JSC 62809

Constellation Spacecraft

Pyrotechnic Specification

Revision C

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National Aeronautics and
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Lyndon B. Johnson Space Center
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C	06/23/06	Matthew W. Maples (281) 483-9052	Revision from CXP board and CR000023

1.0 SCOPE

This specification is of extremely broad scope and covers requirements for all phases of pyrotechnics use, including design, development, qualification, production, acceptance, shipping, storage, handling, installation, and checkout for Constellation Program spacecraft and launch systems. This specification also contains requirements from the functional system level to those related to specific pyrotechnic devices and components thereof as defined in section 11.0. Control avionics and circuitry, Ground Support Equipment (GSE), and launch accessory systems are also covered.

1.1 APPLICABILITY

This specification is applicable to all Constellation pyrotechnic activities, including NASA Centers, their contractors, subcontractors and suppliers engaged in these activities, including design, development, qualification, production, acceptance, and use of pyrotechnics. This document does not apply to unmanned test flights. The order of precedence is:

a. This specification.
b. Documents referenced in this specification to the extent specified herein.

1.2 PYROTECHNIC COMPONENTS

The requirements of this specification apply to all pyrotechnic components as defined in this document (explosive-loaded and explosively-actuated, non-loaded devices).

2.0 APPLICABLE DOCUMENTS

The following documents of the date and issue shown form a part of this document to the extent specified herein. For documents not marked with a specified date or issue, the issue in effect on the date of the contract shall apply.

2.1 GOVERNMENT

2.1.1 National Aeronautics and Space Administration

JSC 20431	NASA JSC Neutron Radiography Specification Ref. Para. 4.5.2.4.2, 4.5.3.3
JSC 28035	Problem Reporting and Corrective Action for Johnson Space Center Government Furnished Equipment Ref. Para. 10.5
JSC 49774	Standard Manned Spacecraft Criteria for Materials and Processes

	Ref. Para. 3.5, 8.1
JSC/SKD26100132	Performance Specification for NSTS Use of Percussion Primers. Ref. Para. 3.6.16.2
NASA-STD-8739.3	Soldered Electrical Connections Ref. Para 8.2.7
NSTS 37325	Problem Reporting and Corrective Action for Contractor Furnished Equipment Ref. Para. 10.5
NSTS 5300.4(1D-2)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program Ref. Para. 3.3

JSC Design and Procedural Standards

JPR 8080.5	JSC Design and Procedural Standards Ref. Para. 3.6.1
E-1	Mating Provisions for Electrical Connectors Ref. Para. A-1.1.7
E-11	Protective Covers Or Caps For Electrical Receptacles And Plugs Ref. Para. A-1.4
E-15	Electrical Power Distribution Circuits - Overload Protection & Fault Propagation Ref. Para. 8.3.2
E-24	Electrical Wire and Cable Acceptance Tests Ref. Para. 8.4.1
G-1	Equipment Accessibility for Maintenance Ref. Para. 3.6.1.2

G-2	Separation of Redundant Systems Ref. Para. 8.2.3
G-3	Electrical and Fluid Systems Checkout Provisions Ref. Para. 7.3, A-1.4
G-8	Design for Redundancy Verification Ref. Para. 8.1.5
G-18	Safety Precautions - Test and Operating Procedures Ref. Para. 3.2.1, 4.5.1.1, 7.3.5, A-1.4.5

2.1.2 Other

Department of Defense (DOD)

AFJMAN 24-204	Preparing Hazardous Materials for Military Air Shipments Ref. Para. 6.1, 6.1.3
AFSPCMAN 91-710	Eastern and Western Range Safety User Requirements Ref. 3.2.3
DOD 4145.26-M	DOD Contractors Manual for Ammunition, Explosives and Related Dangerous Material Ref. Para 3.5.3.1
MIL-DTL-398	RDX (Cyclotrimethylenetrinitramine) Ref. Para. 3.5.3
MIL-DTL-45444	HMX (Cyclotetramethylenetetranitramine) Ref. Para. 3.5.3
MIL-H-45444 Rev. B	HMX (Cyclotetramethylenetetranitramine) Ref. Para. 3.5.3
MIL-L-3055	Type I Lead Azide

	Ref. Para. 3.5.3
MIL-L-46225	Lead Azide RD-1333 Ref. Para. 3.5.3
MIL-P-116	Preservation, Methods of Ref. Para. 6.1.1.1
MIL-P-387	Pentaerythrite Tetranitrate (PETN) Ref. Para. 3.5.3
MIL-R-398 Rev. C	RDX Explosive Ref. Para. 3.5.3
MIL-S-22473	Sealing, Locking and Retaining Compounds, Single Component Ref. Para. 3.6.5
MIL-STD-286	Military Standard Propellants, Solid: Sampling Examination and Testing Ref. Para. 3.5.2
MIL-STD-810 Rev. C	Environmental Test Methods and Engineering Guidelines Ref. Para. 3.8.2, 3.8.3
MIL-STD-2073-1	Department of Defense Standard Practice for Packaging Ref. Para. 6.1.1.1
MS20003	Indicator, Humidity, Card, Three Spot, Impregnated Areas Ref. Para. 6.1.1.1

Federal

CFR, Title 49	Code of Federal Regulations, Title 49 (Parts 100 through 199), Department of Transportation Ref. Para. 6.1, 6.1.3.2

2.2 NON-GOVERNMENT

WS 5003F	Material Specification for HNS Explosive Ref. Para. 3.5.3

Industry Standards and Specifications

AIA/NAS NASM20995	Wire, Safety or Lock Ref. Para. 3.6.5
ANSI/ASQC Z1.4	Sampling Procedures and Tables for Inspection by Attributes Ref. Para. 3.3, 3.3.1
ANSI/NCSL Z450-1	Calibration Laboratories and Measuring and Test Equipment - General Requirements Ref. Para. 7.3.8
ASME Y14.100	Engineering Drawing Practices Ref. Para. 3.4.3
ASME B46.1	Surface Roughness, Waviness and Lay Ref. Para. 3.6.7
ASTM E8	Standard Test Methods of Tension Testing of Metallic Materials Ref. Para. 3.5.8.1
ASTM E1742	Standard Practice for Radiographic Examination Ref. Para. 4.5.2.4.1, 4.5.3.2
IATA DGR	International Air Transport Association Dangerous Goods Regulations Manual Ref. Para. 6.1
SAE ARP5412	Aircraft Lightning Environment and Related Test Waveforms Ref. Para. 8.3.2

SAE ARP5413	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning Ref. Para. 8.3.2
SAE ARP5414	Aircraft Lightning Zoning Ref. Para. 8.3.2
SAE ARP5415	User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning Ref. Para. 8.3.2
SAE ARP5416	Aircraft Lightning Test Methods Ref. Para. 8.3.2
SAE ARP5577	Aircraft Lightning Direct Effects Certification Ref. Para. 8.3.2

3.0 REQUIREMENTS

3.1 RELIABILITY

All pyrotechnic devices and systems shall comply with the applicable provisions of the pertinent flight vehicle specifications. All devices whose functions are required for the safe recovery of the CEV and crew shall not be less than fail-safe (TBR). Elimination of single failure points is the primary reliability consideration in the design of pyrotechnics. Each redundant path shall be verified by test.

3.2 SAFETY

Only personnel formally trained and/or certified in the installation of spaceflight pyrotechnics shall handle, test, or install pyrotechnic devices.

3.2.1 Flight Safety

JPR 8080.5, Standard G-18 is applicable.

3.2.2 Ground Safety

Ground safety requirements and procedures shall conform to the requirements launch center specifications and with individual vehicle requirements. No pyrotechnics shall be shipped to any NASA Center without properly notifying the respective pyrotechnics office. Shipping requirements are contained in paragraph 6.2.

3.2.3 Range Safety

Vehicle designs shall meet the range safety requirements of AFSPCMAN 91-710. For the Constellation Program, specific system/component design requirements shall be tailored from the AFSPCMAN 91-710 requirements through DOD/NASA negotiations and documented in a program level specification for Range Safety.

3.3 QUALITY ASSURANCE (QA)

The QA program shall satisfy the requirements of NSTS 5300.4(1D-2), Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program, to ensure that all pyrotechnics are manufactured in conformance with the requirements of all applicable documents and satisfy the design requirements and intent. These provisions shall be implemented and maintained throughout all phases of design, development, manufacturing, testing, handling, transportation, storage, and installation. Inspection levels shall be established by the appropriate NASA design center's QA office and shall conform to ANSI/ASQC Z1.4, Sampling Procedures and Tables for Inspection by Attributes.

3.3.1 Sampling

Use of sampling inspection and sample plans shall be approved by the appropriate NASA design center QA organization. When used, sampling inspection shall be in accordance with ANSI/ASQC Z1.4, with the following exception: Whenever sampling inspection reveals one or more nonconforming items and the sampling plan does not require rejection of the lot, all items in the lot shall be inspected for the identified nonconforming characteristic.

3.4 SELECTION OF DEVICES, SPECIFICATIONS, AND STANDARDS

3.4.1 Initiator Selection

The NASA Standard Initiator (NSI) shall be used for all criticality 1 (fails to operate failure modes) applications (separate designs may be used for mechanically initiated devices). Appendix A-1 shall be used for NASA Standard Initiator's (NSI's). Any new initiator designs shall go through a comprehensive qualification program that shall be approved by the JSC pyrotechnic office.

3.4.2 Selection of Pyrotechnic Devices and Assemblies

The selection process shall minimize the number of different devices, styles, and generic types in the pyrotechnic system.

3.4.3 Drawing Standards

Throughout the life cycle of the hardware, the design entity shall maintain revision and release configuration control of their drawings and associated files. The drawings shall be consistent with an internal engineering drawing practice standard or follow a NASA approved standard such as ASME Y14.100. The design entity drawing standard shall be made available upon request for NASA audit. The approval cycle shall include appropriate technical discipline review such as materials, stress, and quality assurance, as a minimum. The design entity is responsible for certifying appropriate internal technical reviewers.

3.5 MATERIALS

All materials shall be of high quality and shall be capable of withstanding the ground and flight environments specified for the device. Material selection shall be performed in accordance with JSC 49774.

3.5.1 Prohibited and Restricted Materials

The use of copper or its alloys is prohibited where it can come in contact with Lead Azide or other materials with which copper or its alloys exhibit any incompatibility whatsoever.

3.5.2 Propellant, and Pyrotechnic Materials

All explosive materials, including propellants and pyrotechnics, shall be approved by the appropriate NASA Project Office. Special consideration will be given to suppliers using propellants that are manufactured to industry accepted or NASA standards. Only one lot of each explosives or pyrotechnic material shall be used in the manufacture of any production lot of devices. Each lot of propellant used shall have a propellant description sheet included in the acceptance data package. The propellant description sheet shall state the following as a minimum:

1. Constituents of propellant and percentages used
2. Particle size and or dimensions
3. Heat of Explosion (bomb calorimetric) test performed per MIL-STD-286
4. Ballistic properties

The contractor shall submit a standard comparison sample of suitable quantity (depending on the amount of propellant used in the device) to the responsible NASA pyrotechnic office for each type of propellant used in qualification of flight hardware. This sample will be used to validate future age life test data.

3.5.3 High Explosive Materials

The use of reclaimed high explosive materials is prohibited. The number and types of high explosives in the space vehicle system shall be minimized. HNS, HMX, and RDX are the preferred high explosive materials. Lead azide use shall be limited to those applications where it has been demonstrated that a less sensitive material will not meet the reliability requirements. When used, lead azide shall be encapsulated or otherwise isolated from organic materials, copper, and copper containing alloys. All high explosives shall be procured to the following specifications; the use of alternate revisions of specifications listed below may be permitted when approved by the appropriate NASA design center:

Material	Specification

HNS	WS 5003F
HMX	MIL-DTL-45444 Or MIL-H-45444B
RDX	MIL-DTL-398 Or MIL-R-398C
PETN	MIL-P-387
Lead Azide, Type I	MIL-L-3055
Lead Azide, RD-1333	MIL-L-46225

A NASA letter of certification is required for contractors to procure RDX directly from the U.S. Army Armament Command. Requests for such letters shall be forwarded to the appropriate NASA Project Office for action. Each lot of high explosives shall be tested/analyzed for conformance to the applicable military specification requirements. Whenever practical, high explosives shall be procured directly from the original manufacturer. A certification of conformance, including original test/analysis results from the explosive manufacturer, shall be supplied with each lot of high explosive material.

If the high explosive lot was procured directly from the original explosive manufacturer, and five years or less has elapsed between the date of manufacture of the high explosive lot and the loading date of NASA pyrotechnic devices, the explosive manufacturer's original test/analysis results may be used as the basis for determining acceptability of the explosive lot. If the high explosive lot was not procured directly from the original explosive manufacturer, or more than five years has elapsed between the date of manufacture of the high explosive lot and the date of loading of NASA pyrotechnic devices, a new test/analysis shall be performed prior to the start of loading operations. The original explosive manufacturer, or a suitable test facility approved by the element contractor and cognizant NASA design center, may perform this test/analysis. Test/analysis of high explosive materials shall be repeated within five-years prior to loading into a device if more than five years has elapsed since the original test. If the explosive material is processed or modified in any way after manufacturing, it shall be retested to ensure the processing did not affect performance of the explosive.

Test/analysis results shall be compared with the original test/analysis results for evidence of significant degradation that could impact the functional performance or shelf life of the affected pyrotechnic devices. The results of subsequent tests/analyses shall be compared with all prior tests/analyses results for evidence of significant degradation that could impact functional performance or shelf life. In the event the test facility performing the test/analysis of the high explosive materials wishes to utilize test methods different from those prescribed in the applicable military specification, detailed test procedures shall be prepared and submitted to the appropriate NASA center and element contractor, as applicable, for approval.

3.5.3.1 Explosive Material Contamination Control

Special precautions shall be taken to ensure that explosive material drawn for production use does not become contaminated. Specific instructions for in-process explosive material storage and handling shall be incorporated in supplier pyrotechnic device manufacturing procedures.

Bulk explosive materials shall be stored using techniques that satisfy the requirements of DOD 4145.26-M, DOD Contractors Manual for Ammunition, Explosives and Related Dangerous Material. In order to ensure that explosive materials do not become contaminated, special emphasis shall be placed on good housekeeping, container integrity, container placement, and elimination of all contaminant-promoting conditions. In addition, a rodent and insect-abatement program shall be instituted to prevent possible contamination from those sources. Detailed procedures shall be prepared by each pyrotechnic device supplier to preclude contamination of bulk explosive materials.

These procedures shall be approved by the cognizant element contractor and NASA center.

3.5.4 Compatibility

All materials used in pyrotechnic devices shall be compatible with each other to the extent that no reaction occurs which might adversely affect the component or system performance or safety including transient compounds, liquid or gaseous, generated during curing or storage. Stability and compatibility testing shall be conducted on all explosive/component interfaces, including sealing materials, where test data or analyses for demonstrating stability of materials or compatibility of components is not available.

3.5.5 Proprietary Materials and Processes

The use of proprietary materials and processes shall be avoided whenever possible. Complete disclosure of all proprietary materials and processes shall be provided to the responsible NASA pyrotechnic office for approval.

3.5.6 Protective Treatment

Materials and parts that are subject to corrosion shall be treated with a protective coating that will not crack, chip, peel, or scale with age or when subjected to the environmental extremes applicable to the specific part or device.

3.5.7 Dissimilar Metals

Dissimilar metals which tend toward active electrolytic or galvanic corrosion when in direct contact with each other shall not be used in applications requiring direct contact. Compatible couples are defined in JSC 49774.

3.5.8 Material Certification, Component Parts

3.5.8.1 Tensile Testing of Metallic Parts

Tensile test data shall be required for component parts which are heat treated after machining. Tensile test data shall also be required for component parts which are required to withstand operating pressures and/or primary structural loads.

A minimum of three standard tensile coupons, in accordance with ASTM E8, shall be processed with the component parts. Prior to acceptance, the supplier shall conduct tensile tests on each coupon as defined by the procuring agency, or if no specific direction is provided, tensile testing shall be completed in accordance with ASTM E8.

The following data shall be obtained from the test coupons and recorded on the lot acceptance data sheets:

a. Ultimate Strength

b. 0.2% Offset Yield

c. Elongation

d. Reduction of Area

Failure to meet the minimum material tensile acceptance criteria shall be cause for rejection of the component parts associated with those test coupons.

For pyrotechnic device metallic component parts which are not heat treated after machining and are not exposed to operating pressures or primary structural loads, the standard mechanical properties test report delivered with the raw material will suffice, provided all test data required by the material specification is included in the report.

3.5.8.2 Chemical Analysis

Chemical analysis reports for all materials are required. For components where chemical analysis data is not available, the appropriate NASA design center may authorize substitution of a manufacturer's Certificate of Compliance (C of C).

3.6 DESIGN DEVELOPMENT TECHNOLOGIES AND PRACTICES

3.6.1 NASA/JSC Standards

Pyrotechnic devices and systems shall comply with the requirements of JPR 8080.5, JSC Design and Procedural Standards.

3.6.1.1 General Requirements

All design and construction details should provide for maximum reliability, safety, and operating efficiency, as well as for minimum weight. Performance margins shall be provided in the designs to provide for charge variations and tolerances. No components shall work loose and all components shall be capable of withstanding strains, impacts, vibration, and other conditions incidental to shipping, storage, installation, and service.

The alignment and fit of parts and mating surfaces shall assure proper functioning within the specified environmental extremes.

3.6.1.2 Accessibility

Pyrotechnic systems shall be designed for optimum accessibility of all subsystems, assemblies, and components. Components shall be located near existing access panels and work platforms, where possible. Cartridges and independently installed initiators shall be located near the first point of entry to facilitate installation and change out. JPR 8080.5, Standard G-1 is applicable.

3.6.1.3 Maintenance

Maintenance of pyrotechnic devices installed on the vehicle shall be limited to removal and replacement. No scheduled maintenance shall be performed on pyrotechnic subsystems and devices (except firing circuits and components) after vehicle installation.

3.6.2 Installation, Replaceability, Maintainability, and Interchangeability

Installation of all components and subsystems shall be controlled by detailed procedures specifying step-by-step details, including techniques and the equipment to be used for inspection. Provisions shall be made for design tolerances and buildups such that items having the dimensions and characteristics permitted by the item specification or drawing are interchangeable without selection or departure from the specified equipment performance. Appropriate warnings pertaining to the fragility and hazardous nature of pyrotechnic devices shall be incorporated into all assembly and installation procedures. Wherever practicable, but consistent with the provisions of Paragraph 3.6.1.2, the loaded pyrotechnic device (e.g., initiator or cartridge assembly) shall be designed to be accessible for inspection and/or change out. Refer to Paragraph 4.6.1 for thread size restrictions. Adjacently located cartridges shall be designed in accordance with JPR 8080.5, Standard E-1. Pyrotechnic devices shall not be installed in the proximity of heat sources that could cause ignition or degradation of the pyrotechnic components.

3.6.3 Explosive Interfaces

All explosive interfaces (e.g., detonator-to-booster) and other initiator or detonator transfer connections shall be designed and installed to ensure positive gap and angle control. Joints and interfaces shall be standardized to the greatest possible extent. Optimum spacing and margins for initiation and detonation transfer joints shall be determined and demonstrated by gap separation and/or angle and offset tests. Unless different explosive materials are known to be compatible, they shall be separated by inert barriers.

3.6.4 Sealing

All pyrotechnic devices shall be appropriately sealed to protect explosive materials from contaminants and exposure to vacuum environment. The sealing process shall in no way change the electrical characteristics of the initiator, when used. Where sealing is accomplished by non-metallic seals (e.g., metal end-caps bonded to Linear Shaped

Charge [LSC]/Mild Detonating Fuse [MDF] with adhesive), end-to-end electrical conductivity shall be maintained to assure that there is no buildup of electrical charge potential.

3.6.5 Locking Threaded Parts

All threaded parts shall be positively locked. Appropriate control procedures shall be established for the reuse of self-locking devices where applicable. Acceptable locking methods are as follows:

a. Metallic Self-Locking Nuts
b. Castellated Nuts and Cotter Pins
c. Lockwire conforming to AIA/NAS NASM20995, Wire, Safety or Lock
d. Screw-Locking Screw Thread Fasteners
e. Welding, Brazing, or Soldering
f. Sealant per MIL-S-22473, Sealing, Locking and Retaining Compounds, Single Component
g. Roll Pin
h. Epoxy Type Sealants Qualified for the Intended Use
i. Nylon or other non-metallic insert thread locking devices may be used when environmentally appropriate.

3.6.6 Screw Threads

Class 3 threads shall be utilized unless approval for use of other thread classes is granted by the appropriate NASA design center. Non-Destructive thread inspection methods shall be approved by the appropriate NASA design center.

3.6.7 Surface Wear

Mating surfaces shall be sufficiently smooth and wear-resistant to minimize the generation of metal-to-metal and seal wear particles. Surface roughness shall be indicated in accordance with ASME B46.1, Surface Roughness, Waviness and Lay.

3.6.8 Prohibited and Restricted Practices

3.6.8.1 Insulation Resistance (IR) Testing

Insulation resistance test criteria shall be established on all electrically initiated pyrotechnic devices. The number of insulation resistance tests shall be minimized.

3.6.8.2 Dielectric Testing

Dielectric testing of any pyrotechnic device is prohibited.

3.6.9 Electrical Bonding

Electrically initiated pyrotechnic devices or those containing primary explosives shall be designed so that electrical resistance between the metal exterior of the device and the next adjoining device or contact surface, if mechanically joined, shall be 2.5 milliohms or less.

3.6.10 Mockups

Except as otherwise required, pyrotechnic mockups shall use production hardware without charges or with dummy or inert charges. All mockups of explosively loaded components shall be color coded blue.

3.6.11 Blast Containment

All pyrotechnic devices shall be adequately contained to pose no hazard to crew, vehicle or mission.

3.6.12 Locked-Shut Capability

Pressure actuated devices shall be capable of withstanding internal pressures generated in operation with the movable part restrained in its initial position and without rupture or the release of shrapnel, debris, or hot gases which could compromise crew safety or mission success. Where applicable, this capability shall be demonstrated with redundant charges operating simultaneously.

3.6.13 Yield Factor

The yield factor shall be a minimum of 1.1 applied to the limit load. Components shall have adequate strength to withstand limit loads without loss of operational capability for the life of the component. (This factor is not applicable to the loads generated by the firing of the pyrotechnic charge).

3.6.14 Design Ultimate Factor of Safety

The design ultimate factor of safety shall be a minimum of 1.4 applied to the limit load. Components shall have adequate strength to withstand ultimate loads without failure. The 1.4 factor is not applicable to loads generated by the firing of the pyrotechnic charge. When the ultimate tensile strength of a selected material is more than 1.4 times the yield strength of the material, the design shall be based on the limit load and the yield strength of the material.

3.6.15 Special Tools

Pyrotechnic devices shall be designed to require a minimum of special assembly and installation tools.

3.6.16 Initiation Mechanisms and Devices

3.6.16.1 Electro Explosive Device (EED)

EED shall be as specified in Paragraph 3.4.1.

3.6.16.2 Mechanical Initiation Devices

Mechanical initiation shall be accomplished using percussion primers conforming to the following specifications:

Primer Type	Specification
M42 C1	JSC/SKD26100132
M42 C2	JSC/SKD26100132

The use of new primer designs is acceptable as long as the testing requirements of the JSC/SKD26100132 are met. Certifications and associated testing shall be submitted and approved by the responsible Project Office. The certifications and associated testing required by this specification apply to the primers prior to their installation into the next higher assembly. Subsequent to their installation, testing of the next higher assembly is sufficient to demonstrate the continued acceptability of the installed primers.

3.6.17 Propellant Operated Devices

3.6.17.1 General

For this type of device a separable cartridge assembly is preferred over an integral charge for safety, ease of installation and replacement, and to allow flexibility of installation scheduling during pre-launch operations. All components exposed to operating pressure shall be capable of withstanding the following pressures:

a. An internal static proof pressure of 1.2 times the maximum operating pressure without permanent deformation or leakage. The maximum operating pressure is defined as the highest measured operating pressure from a minimum of five firings using nominal cartridge load. If the cartridge design, propellant or application make direct pressure measurements impractical or if a measured transient pressure spike establishes an unrealistic proof pressure requirement, an analytically derived proof pressure requirement may be established. This analysis shall be approved by NASA Engineering, NASA Safety & Mission Assurance (S&MA) and the Project Office at the responsible field center. This requirement must be demonstrated on all qualification and production hardware.

b. An internal burst pressure of 1.25 times the proof pressure level as determined in Paragraph 3.6.17.1a without structural failure (burst).

c. A locked-shut firing test, without fragmentation, shall be conducted to demonstrate this capability for devices such as mortars, thrusters, and circuit interrupters.

3.6.17.2 Cartridge Torque

Each cartridge assembly shall be capable of withstanding 1.5 times the specified maximum allowable installation torque without physical damage.

3.6.18 High Explosive Operated Devices

3.6.18.1 Linear Shaped Charge (LSC), Mild Detonating Fuse (MDF), and LSC/MDF Assemblies

LSC and MDF shall be standardized as to size, core loading, sheath materials, type of explosive, configuration, end coupler and booster design to the greatest possible extent without compromising performance or reliability.

3.6.18.1.1 Core Charges

A production lot shall consist of all LSC/MDF produced in a single production run. It may consist of LSC/MDF made from more than one tube; however, only one lot of bulk explosive and tube materials shall be used in one lot of LSC/MDF. A tube shall be a length of tubing loaded with explosive material prior to being reduced to the required configuration.

3.6.18.1.2 Sheath Geometry

Sheath geometry, thickness, apex thickness (for LSC) and concentricity (for MDF) shall be established for each core charge.

3.6.18.1.3 Explosive Material

LSC/MDF core explosive shall be selected in accordance with Paragraph 3.5.3 and 3.5.4 and the core load, in grains per foot, shall be verified in accordance with Paragraph 4.5.3.4.1.

3.6.18.1.4 Splicing

LSC/MDF core charges shall not be spliced.

3.6.18.2 Charge Holder Assemblies

Where appropriate, LSC/MDF core charges and explosive trains shall be mounted in charge holders to protect the explosive components from damage. Assembly of the explosive items into charge holders at the supplier is preferred to provide increased protection from damage during shipping and handling operations.

3.6.18.2.1 LSC Assemblies

LSC charge holders shall be designed to permit inspection of the standoff and/or provide dimensional control of the standoff after installation. Provisions shall be made to ensure that no contamination enters the LSC apex area after installation into the charge holder or installation of the charge holder into the next higher assembly. When redundancy is required and dual charges are utilized to meet this requirement, a separation barrier shall be used to prevent dudding of one charge by the other. At least one initiation point is required for each charge and either charge shall be capable of performing the required function. Piggyback configurations shall not be used to achieve redundancy. The capability of a redundant design to prevent dudding and the proper performance of both charges shall be demonstrated during qualification.

3.6.18.2.2 MDF Separation Assemblies

MDF separation systems shall utilize multiple initiation points and dual MDF core charges. MDF core charges shall be positioned side-by-side in the charge holder assembly and either charge shall be capable of performing the separation function. This capability shall be demonstrated by test. The capability of a redundant design to prevent dudding and the proper performance of both charges shall be demonstrated during qualification.

3.6.19 Frangible Devices

3.6.19.1 Frangible Bolts

A 15% margin shall be demonstrated in a manner dependent on the design of the device. Frangible devices shall be capable of the required performance with a production cartridge/charge. If multiple cartridges/charges are used to achieve redundancy, this requirement must be satisfied using a single cartridge/charge. This test should be performed under the minimum allowable loading conditions that can exist at the time of functioning of the frangible device.

3.6.19.2 Frangible Nuts

The margin shall be demonstrated by firing a production cartridge in a nut having a separation cross section that is 115% of the maximum allowable cross section. The margin requirement shall be demonstrated on each production lot. If multiple cartridges/charges are used to achieve redundancy, this requirement must be satisfied using a single cartridge/charge. This test should be performed under the minimum allowable flight loading conditions that can exist at the time of functioning of the frangible nut.

3.6.20 Guillotines and Cutters

When severing electrical wires with a guillotine or cutter, the possibility of electrical shorting during and/or after operation shall be considered and appropriate protection shall be provided. A performance margin shall be demonstrated by either firing a production cartridge (charge) in the device and cutting at least 115% of the target material or by using a cartridge 85% (by weight) of the minimum allowable charge with a 100% target material. The device shall not fragment when fired with 115% (by weight) of the maximum output charge. For dual blade devices this capability (no fragmentation) shall be demonstrated with 115% (by weight) of the maximum output charge installed in each blade and both blades fired simultaneously.

3.6.21 Safe and Arm (S&A) Devices

The following requirements apply to S&A devices utilized in conjunction with ordnance functions on the space vehicle.

a. The ignition train shall begin with two initiators.
b. The ignition train will perform its desired function when one or both of the initiators are fired with the S&A device(s) in the armed position.
c. The S&A device(s) shall, by means of a mechanical barrier, prevent propagation of the ignition train when one or both of the initiators are fired

with the S&A device(s) in the safe position. The barrier shall rotate a minimum of 90° between the S&A positions.

d. The S&A device shall be capable of remote positioning from safe-to-arm and arm-to-safe through simplex command and control circuits and simplex actuation devices.

e. The S&A device shall provide remote simplex electrical position indication. The position indicator switches shall be attached to or directly actuated by the mechanical barrier.

f. The S&A device shall provide direct visual position indication in both the safed and armed positions. The armed indication will not be visible unless the device is in such a position that the ordnance train in it will propagate past the mechanical barrier.

g. A partially “armed” S&A device shall be capable of remote electrical arming and safing.

h. The S&A device shall incorporate a positive mechanical linkage to maintain the device in either full “armed” or “safed” position. Electrical arming and both electrical and mechanical safing shall be capable of overriding this mechanical linkage.

i. The S&A device shall be provided with a mechanical lock pin which, when manually installed, shall prevent rotation of the barrier. The pin may be installed while the device is in any position between full “safe” and full “arm” and shall return the device from any position to the “safe” position without passing through the “arm” position.

j. The S&A device mechanical lock pin shall not be removable when the “arm” command circuit is energized, but can be removed after de–energizing.

k. The S&A device shall prevent manual arming.

l. The electric initiators or the entire S&A device(s) shall be separable from the remainder of the ordnance train.

m. The S&A device shall be environmentally sealed so that the leak rate will not exceed 1.0×10^{-2} scc/sec of helium with a differential pressure of 15 psi.

n. The S&A device electrical power requirements and electrical connectors shall meet the requirements specified by the procuring agency.

o. The initiation of one initiation path shall not dud the redundant path. This shall be verified by qualification test.

p. With the mechanical lock pin installed, the application of the arm command for one hour shall not degrade the electrical or pyrotechnic performance of the S&A Device.

3.6.22 Unique Pyrotechnic Requirements

3.6.22.1 Handling Drop Test (Eight Foot Drop)

Pyrotechnic loaded devices shall be capable of being dropped from a height of eight feet (TBR) minimum without firing as a result of the drop. The device shall be fired after the drop and shall meet the Destructive Lot Acceptance Testing (DLAT) firing performance characteristics unless obvious damage, which occurs during the drop, compromises the functional reliability of the device. Obvious damage is any condition which would be identified during normal pre-installation inspection. Thread damage as a result of the drop may be repaired in order to perform the firing. This requirement does not apply to S&A devices.

3.6.22.2 Installation Safety Drop Test (Forty Foot Drop)

Pyrotechnic loaded devices shall not create a safety or disposal hazard as a result of a drop from a height of 40 feet.

3.6.22.3 Auto-Ignition

Explosive materials selected shall not auto ignite when subjected to 50°F (10 C) above the maximum expected thermal exposure for which the device is designed. The device shall be exposed to that temperature for a minimum of one hour. The device is not required to function afterwards.

3.6.22.4 Eighty-Five Percent Minimum Energy Test

Each pyrotechnically loaded device shall be capable of performing its function with 85% of the minimum allowable charge weight. Because of the difficulty in downloading some devices to 85% of the minimum charge weight, increased thickness of target material or increased fracture area is the required method of meeting this requirement in those cases. Suggested methods of meeting this requirement for the following types of pyrotechnic devices are provided as a guide. Other methods are acceptable if adequate technical justification is provided. This requirement must be satisfied during qualification testing.

Devices that have the sole function of transferring detonation/energy within a pyrotechnic system are exempt from this requirement. This exemption includes delay fuses, initiators, NASA Standard Detonator's (NSD's) and columns. This exemption does not apply to Thru Bulkhead Initiators (TBI's).

3.6.22.4.1 Linear Shaped Charge

Margin can be demonstrated by the severance of 115% of the maximum thickness of the material to be severed in actual use or verification of a 15% penetration margin by the use of a suitable test target material. Material thickness of 115% or penetration margin of 15% is required.

3.6.22.4.2 Thru-Bulkhead Devices

Proper transfer across the bulkhead shall be demonstrated by loading the donor and acceptor charge by the force method only, using 85% of the minimum allowable explosive charge weight in each cavity.

3.6.22.4.3 Mild Detonating Fuse (MDF)

When an MDF is used to fracture a structural element, this requirement may be demonstrated by downloading the MDF to 85% of the minimum allowable charge weight or by increasing the structural element to 115% of the maximum allowable size.

3.6.22.4.4 Pressure Actuated Devices

Pressure actuated devices must be capable of the required performance with a single cartridge loaded with 85% of the minimum allowable charge weight unless the margin requirements can be met by other means mentioned above. If multiple cartridges are used to achieve redundancy, this requirement must be satisfied using a single 85% cartridge.

3.6.22.5 One Hundred Fifteen Percent Maximum Energy Test

Each pyrotechnically loaded device shall be capable of performing its function with 115% of the maximum allowable charge weight. Other suitable methods may be applied such as adding powder into the firing cavity. This requirement must be satisfied during qualification testing. Devices should not be specifically fabricated to permit 115% overload if internal dimensions of the device do not permit overloading.

Devices that have the sole function of transferring detonation/energy within a pyrotechnic system are exempt from this requirement. This exemption applies to delay fuses and columns, Shielded Mild Detonating Cord’s (SMDC’s), Flexible Confined Detonating Cord’s (FCDC’s), and Confined Detonating Fuse (CDF) Assemblies.

The following types of devices must meet this requirement without structural failure.

3.6.22.5.1 Thru Bulkhead Initiator (TBI)

Proper transfer across the bulkhead must be demonstrated by loading the donor and acceptor charge by the force method only using 115% of the maximum allowable charge weight in each cavity. There shall be no leakage through the bulkhead after this test. The Thru-Bulkhead Initiator (TBI) bulkhead critical design dimensions shall not be altered to accommodate overloading of explosives (e.g., machining of a special device to permit accommodation of 115% load in donor or acceptor cavities). Other suitable methods of testing bulkhead strengths shall be applied (e.g., booster pellets or hydraulic pressure).

If leakage after firing will not compromise system performance or safety, this requirement is waived.

3.6.22.5.2 Pressure Actuated Devices

Pressure actuated devices must be capable of the required performance with a cartridge loaded with 115% of the maximum allowable charge weight. If multiple cartridges are used to achieve redundancy, this requirement must be satisfied with both cartridges loaded to 115% of the maximum allowable charge weight. The cartridges must be fired simultaneously during the performance of this test.

3.6.22.5.3 Mild Detonating Fuse (MDF)

When an MDF is used to fracture a structural element and containment of the detonation products is a part of the design, this requirement must be satisfied. The MDF must be loaded with 115% of the maximum allowable charge weight for this test. The structural element and the containment method must be the minimum allowed by the design.

3.7 LIFE AND AGE CONTROL

3.7.1 Design Life (Age Life)

3.7.1.1 Definition

The design life (also known as age life) is the life over which a pyrotechnic component is designed to perform its intended function.

3.7.1.2 Age Life

The design life of explosively loaded pyrotechnic devices shall be a minimum of 10 years from the date that the Destructive Lot Acceptance Testing (DLAT) is performed.

3.7.1.3 Age Life Testing

Age life tests shall demonstrate that the performance characteristics continue to meet the lot acceptance criteria without significant degradation. The method by which age life may be extended on a specific component (functional testing of samples from the lot, functional testing of recovered flight units, and/or evaluation of flight performance) shall be approved by the responsible NASA design center. Repetition of all lot acceptance tests is not required for shelf life testing. Devices removed and replaced every flight shall be functioned at the temperature environment(s) demonstrated in DLAT at a minimum. Age life performance tests may be conducted at the launch site, supplier's facility or other appropriate test facility using lot acceptance procedures or other procedures approved by the appropriate NASA design center. Each age life test shall consist of a minimum of five units each. Shelf life testing shall include quantifiable measures of performance (instead of go/no-go tests) unless authorized by the appropriate NASA design center. The tests shall be performed at specific intervals as designated in the Age Life Extension Test Table below.

Age Life Extension Test Table		
Extension Schedule	Time Frame to Perform Test (From Acceptance Date$_{1,2}$)	Expiration Date (from Acceptance Date)
4 Year Test	3.5 – 4 years	7 years from Acceptance Date
7 Year Test	6.5 – 7 years	10 years from Acceptance Date
10 Year Test	9.5- 10 years	11 years from Acceptance Date
Beyond 10 Years	Up to 6 months prior to expiration	1 additional year from previous

		Expiration Date

Footnotes:

1. Acceptance Date for explosive cord is taken from the date the original Velocity of Detonation on the cord is completed.

2. The Acceptance Date for all other devices is the date that DLAT is completed.

3.7.1.3.1 Functional Testing of Samples from the Lot

Lot samples shall be randomly chosen when practical.

3.7.1.3.1.1 Environmental Conditioning

Environmental conditioning shall be performed on test units. The extent of environmental conditioning shall be the responsibility of the applicable NASA design center.

3.7.1.3.2 Functional Testing of Recoverable Flight Units

Recoverable flight units are acceptable for age life samples.

3.7.1.3.3 Evaluation of Flight/Ground Performance

Flight/ground performance may be used for age life extension if no degradation of performance of a device can be verified. The performance of devices from the same lot on multiple flights may be used to meet the five-firing minimum requirement. When performance from multiple vehicle flights is used, the age life of a lot shall be extended based on the date of the earliest flight. Pyrotechnic component flight performance in redundant systems in which proper operation of an individual device can not be verified shall not be used to extend age life. Recoverable flight units are acceptable for age life samples. The responsible NASA design center or designated contractor shall identify, perform and evaluate any teardown and disassembly of the test articles.

3.7.1.3.4 Age Life Testing of LSC, MDF, CDC, FCDC, CDF and SMDC

Sub-length Linear products manufactured in a lot of production hardware may be used for shelf life evaluation. The target material for Linear Shaped Charge LSC shall be the same as that used for lot acceptance testing.

3.7.1.3.5 Age Life Testing of Linear Charge Assemblies

Multiple production lots of linear charge assemblies (e.g., CDF assemblies, x-cord, etc.) whose explosive cord has been manufactured in one continuous cord production run may be shelf life tested as a single lot and the test results shall apply to each of the production lots.

3.7.1.4 Certification

The age life shall be tracked from the date of the DLAT of the loaded component, except for the initiator where the age life shall be tracked from the manufacturing date. In the case of those components containing multiple pyrotechnic elements that are controlled by the responsible NASA design center (primers, initiators, delay trains, booster charges, etc.), the age life shall be tracked from the date of the DLAT of the component without regard to the DLAT of the pyrotechnic elements. In the case of components containing explosive cord, the age life shall be tracked from the date of the original velocity of detonation acceptance test.

3.8 ENVIRONMENTS

3.8.1 Mission Environments

3.8.1.1 Mission Cycles

Pyrotechnic devices not normally expended on each mission shall be exposed to repeated vibration, shock, humidity, and thermal cycling environments to qualify the device for repeated mission usages. These environments shall be consistent with the planned number of missions projected during the installed life of the device or for the planned remove and replace interval.

3.8.2 Natural and Induced Environments

Pyrotechnic devices shall be designed to withstand, without damage or impairment of performance, as a minimum, the environments in MIL-STD-810C, Environmental Test Methods and Engineering Guidelines, required by the item specification.

3.8.3 Transportation Environments

Transportation environments shall be in accordance with MIL-STD-810C.

3.9 TRACEABILITY AND IDENTIFICATION

3.9.1 Traceability

All pyrotechnic devices shall be traceable by lot (reference Paragraph 3.11.1) and serial number. Components and materials which are not susceptible to serialization, such as percussion primers, shall be traceable by lot.

3.9.2 Identification of Product

Pyrotechnic devices shall be permanently and legibly marked with the part number, lot number, vendor Contractor And Government Entity (CAGE) code, manufacture date and serial number. Part number and lot number shall be NASA and/or Prime Contractor designations based on direction from the appropriate NASA design center. Shipper identification tags shall show all information required by the purchase order.

3.9.3 Lot Designators

Each lot of pyrotechnic devices shall be identified by a three-letter designator (e.g., AAA, AAB...) which shall not be repeated for any part numbers. Production lot designator shall not begin with the letters D, I, O, Q, U, X, and Z. The letters I, O, Q, and Z shall not occupy any lot designator position. The letters D and X in the first letter are reserved for development and payload hardware use. The letter U is reserved to designate qualification lot hardware.

3.9.4 Color Coding

Color coding of pyrotechnic devices shall be in accordance with the following requirements. Flight operational units shall be the natural color of the body material (stainless steel, aluminum, etc.). Painting of pyrotechnic devices to limit reflective properties or heat absorption is not permitted unless it is approved by the respective pyrotechnics office prior to use.

The following items shall be painted BLUE:

a. Inert expended devices that will not be immediately scrapped
b. Non-flight mockups or dummies of normally loaded pyrotechnic devices

The following Items shall be painted RED:

a. All loaded devices procured for testing, not intended for flight, shall be color coded RED, at the supplier facility.

b. Any lot certified device subsequently found to be discrepant shall be submitted to the Material Review Board (MRB). If the board finds the device “not acceptable for flight”, the device shall be color coded RED by the inspecting agency and dispositioned in accordance with the MRB instructions. Information pertaining to all problem areas requiring MRB action and resulting MRB dispositions shall be transmitted to the cognizant NASA Project Office.

3.10 WEIGHT

Each cartridge shall be weighed individually just prior to loading, weighed after the loading of each charge in the manufacturing sequence, and as a completed cartridge. Detail procedures to ensure that the specified charge weight is present in the completed pyrotechnic device shall be specified in manufacturing procedures approved by the appropriate NASA design center. Representative items such as insulation/isolation discs, spacers, and closures can be used in determining the appropriate tare weight. All incremental weights shall be recorded in the manufacturing records. Energy transfer devices (CDC, CDF and MDF, etc.) are exempt from this requirement.

3.11 PRODUCTION LOT REQUIREMENTS

The requirements of this paragraph pertain to all lots beginning with the qualification lots of the various devices and assemblies and include all lots intended for manned flight use.

3.11.1 Production Lot

Each piece part, component, subassembly, or device shall be of the same design and construction, fabricated in one unchanging and essentially continuous manufacturing process and submitted for acceptance at one time. The single lot control requirements of non-explosive components used in a lot of devices shall be determined, documented and approved by the cognizant NASA design center. Factors such as component function in end item performance and effectiveness of destructive tests in screening defective components will be considered in establishing single lot control requirements. Only one lot of each explosive or pyrotechnic material shall be used in a lot of explosively loaded components or devices. Only one lot of explosively loaded components, such as MDF, shall be used in the manufacture of a lot of the next higher assembly, such as explosive trains. This restriction shall apply to all successive levels of assembly, including the final acceptance level but shall not apply to initiator lots integrally installed (married) into cartridge assemblies.

3.11.2 Lot Size

Each lot shall be sized to include flight, flight spares, test article, age life samples and PVT parts for a selected number of vehicles, plus parts necessary for other uses when required. Specific direction from the NASA Project Office is required for deviations from these sizing requirements with respect to quantity of PVT and flight spare units. In determining lot size consideration shall be given to:

a. Life of the part and component thereof to prevent life expiration prior to the last scheduled use of the lot.

b. Economic benefits of large quantity procurement.

c. Potential cost and schedule impact of a lot-associated failure.

3.11.3 Quantity Started

The number of units in a lot at the start of manufacture shall be limited to parts required for delivery (reference Paragraph 3.11.2) and attrition in manufacturing and acceptance testing. The lot shall not include extra units that are not required as part of the purchase order fulfilling the NASA requirement.

3.11.4 NASA ID Control

The NASA or element contractor part number and lot number identifying vehicle units shall be removed from any units which the manufacturer sells or disposes of outside the NASA certification system. Original serial numbers may be retained.

3.12 CONTAMINATION CONTROL AND FOREIGN MATERIAL

Proper contamination requirements will be observed at all times. Particular care will be taken to assure that there is no contamination of explosive materials on the mating surfaces at the time of assembly. In all assembly operations involving explosively loaded parts, positive protective measures shall be taken to assure that potentially degrading fluids, moisture, foreign materials, or other contaminants are not trapped and/or sealed into assemblies. To prevent contamination of the explosive material(s) with liquids, the supplier’s applicable manufacturing procedures shall specify that each device shall be completely dry prior to sealing and that no liquids are to be utilized for cleaning or sealing preparation after installation of the explosive materials and prior to sealing. The procedures shall specify that the immediate area of explosive operations shall be free of such liquids as methanol, Freon solvents, oils, and alcohol. In the event that spillage of explosive material necessitates cleaning of the loading area with liquids, all parts shall be removed from the area until cleaning is completed, the area is completely dry, and the liquids have been removed. If liquids are used to clean a loaded unit after sealing and prior to leak testing, any unit that fails leak testing shall not be reworked but shall be rejected.

4.0 VERIFICATION

This section delineates the verification methods (analyses and tests) to be performed to verify that the item to be developed or offered for acceptance conforms to the requirements of this specification. The verification phases are categorized as development, acceptance, and qualification. Development includes those activities required to support the design process. Acceptance assures the quality of the deliverable product. Qualification results in assurance that the design will satisfy all specified design requirements. Data from development and acceptance test programs may be used to support qualification requirements provided that appropriate test rigor is applied. Analysis includes appraisal of design features (e.g., transportability, parts standardization) that do not require tests.

4.1 GENERAL REQUIREMENTS

The supplier shall use the following general requirements in developing a certification program. Each performance and design requirement specified herein shall be verified by test or analysis. The general philosophy of the testing programs should focus on establishing performance capabilities in the presence of critical material properties and dimensional extremes within specification limits. Performance of certification tests using nominal materials, dimensions, and processes has not proven adequate for pyrotechnic systems.

4.1.1 Development Testing

Testing performed with minimum rigors and controls to verify a design approach. Development tests should incorporate variations in critical dimensions and properties to probe the expected limits allowable by the appropriate specifications.

4.1.2 Qualification Tests

Qualification tests shall be structured to verify the full range of the design requirements under specified environments as required by Paragraph 3.8.1.

4.1.2.1 Redundancy in Design

Where redundancy in design exists, each redundant mode shall be verified during qualification.

4.1.2.2 Acceptance Testing of Qualification Specimens

All qualification test specimens shall be processed through specific nondestructive lot acceptance testing prior to qualification test.

4.1.3 Off-Limit Testing

Testing performed that is not a component or system design or certification requirement, as defined by the applicable specification, is considered off-limits. Off-limits testing when performed should be included in the development tests and not a part of the qualification requirements. Margin demonstration tests, that are included in the certification requirements, are not considered off-limits.

4.2 DEVELOPMENT TESTS

Development tests encompass standard laboratory tests to support material selection and engineering evaluations of hardware for the purpose of acquiring a data base to establish confidence that the hardware will meet specification requirements. Those tests used to satisfy a qualification requirement must meet the following criteria:

Predeclaration	The intent to use the test for certification is declared prior to conducting the test.
Configuration	Production configuration or approval (where allowed) for differences.
Facilities	Certified
Inspection	Required
Test requirement/ procedure/pass-fail criteria	Formally Approved
Acceptance, prefunctional and postfunctional test	Required
Documentation	Submittal of configuration description, failure reports, and test methods and results.

4.3 ACCEPTANCE

The acceptance requirements shall be satisfied by test or analysis. Acceptance tests shall be performed on all units presented for certification and destructive lot acceptance units that support the certification. The destructive lot acceptance units shall be selected at random to the maximum extent practical. The acceptance requirements shall be documented and a test procedure approved prior to testing.

4.4 QUALIFICATION

Qualification requirements must be individually defined for each component or assembly considering its function, complexity, redundancy, design, and maintenance requirements. These requirements can be satisfied by test, analysis or similarity.

4.4.1 Qualification by Tests

Testing is the basic method to be used in the qualification of flight hardware and Ground Support Equipment (GSE). Such tests are used to determine that the hardware is capable of performing its required operational functions in the known or anticipated environmental conditions. These tests will be designed to subject samples of the hardware to the worst case environments and stresses anticipated. Hardware requiring qualification by test, which is produced to identical design requirements by several manufacturing sources, shall be qualified, by test, for each source. Those environmental tests or stress conditions that would not be affected by a new vendor's process or procedure need not be repeated by test. The basis for this decision shall be documented as a part of the certification process.

4.4.1.1 Test Hardware

Qualification test hardware shall be of the same configuration and manufactured under the same production process as the flight hardware, unless differences are adequately documented and are judged to be acceptable by the certifying agency. The qualification hardware must come from a single lot and this lot may be the first production lot.

4.4.1.2 Test Sequences and Environments

Environments and test sequences must be considered by each element contractor and identified in a test plan and shall be subject to approval by the NASA Project Office associated with the procurement. Testing shall include both natural and induced environments anticipated during the operational cycles. Combined environments shall be used when necessary and practical. Every natural and induced environment which may be imposed during a hardware item's operational life and which can detrimentally affect the item's performance, strength, or life shall be included in the test program.

4.4.1.3 Qualification Tests Unique to Pyrotechnics

4.4.1.3.1 Mission Cycle Life Testing

Pyrotechnic devices not normally expended on each mission shall be qualified to appropriate multiple mission environments which represent the number of mission cycles expected prior to hardware change out and replacement as specified in Paragraph 3.8.1. The number of cycles performed shall be consistent in quantity and magnitude with the projected environmental excursions expected for the duration of hardware installation.

4.4.1.3.2 Handling Drop Test

Pyrotechnic loaded devices shall be capable of being dropped from a height of eight feet (TBR) minimum plus six inches minus zero upon a steel plate (1/2 inch thick minimum) without firing as a result of the drop. The device shall meet the performance requirements described in Paragraph 3.6.22.1. A minimum of three test samples shall be dropped. One unit each will be dropped in each of the three mutually perpendicular axes.

4.4.1.3.3 Installation Drop Test

When this test is specified for a device by the NASA design center, a single test specimen shall be dropped from a height of 40 feet plus six, minus zero inches. The impact surface shall be a steel plate (minimum thickness of three inches) backed up by a minimum of 24 inches of reinforced concrete. The impact orientation of the test specimen with the plate shall be within 10° of that which is determined (by analysis) to be the most sensitive. The unit shall not function as a result of the 40 foot drop test. The unit is not required to function after the 40 foot drop test.

4.4.1.3.4 Auto-Ignition Test

Auto-ignition tests are to be performed to a temperature level 50°F minimum above the maximum expected temperature of the pyrotechnic device in question. Temperature rise rate of the test article and dwell time at maximum temperature shall be derived from the expected exposure cycles of the pyrotechnic device in question.

4.4.1.3.5 Eighty-Five Percent Minimum Energy Test

The device shall be functioned in accordance with the requirements of Paragraph 3.6.22.4. Where multiple explosive components exist within a device, all components must be downloaded simultaneously (initiators, primers, delay columns, detonators and any device with the sole function of transferring energy shall not be downloaded to meet this requirement). For pressure actuated devices, simulated or inert cartridges shall be installed in the redundant cartridge port(s) when conducting this test.

4.4.1.3.6 One-Hundred Fifteen Percent Maximum Energy Test

The device shall be functioned in accordance with the requirements of Paragraph 3.6.22.5. Where multiple explosive components exist within a device, each component must be uploaded simultaneously (initiators, primers, delay columns, detonators and any device with the sole function of transferring energy shall not be uploaded to meet this requirement).

4.4.1.3.7 Locked Shut Testing

Pressure actuated devices shall be capable of withstanding internal pressures generated in operation with the movable part restrained in its initial position and without rupture or the release of shrapnel, debris, or hot gases which could compromise crew safety or mission success. Where applicable, this capability shall be demonstrated with redundant charges operating simultaneously.

4.4.2 Qualification by Similarity

Qualification by similarity is acceptable provided all following conditions are met:

a. Engineering evaluation reveals that design differences between the item being qualified and the previously qualified similar item are acceptable and will have no deleterious effect on integrity and performance.

b. The previously qualified similar item was designed and qualified for equal or higher environmental stress levels and time durations than those known or anticipated for the item being qualified.

c. The item being qualified was fabricated by the same manufacturer as the similar item using the same processes, materials, and quality control methods.

d. Documentation is provided which assures that qualification by similarity is adequate. The submitted documentation should include as a minimum, the test specification/test procedure/test report of the item to which similarity is claimed, a description of the differences between the items and the rationale for qualification by similarity. JPR 8080.5, Standard G-12 is applicable.

4.4.3 Qualification by Analysis

Qualification by analysis is limited to those situations in which it is not feasible or cost effective to qualify by other methods. Such analysis shall be documented to an extent sufficient to provide for an independent evaluation of the results of the analysis. Analysis may be used for those requirements for an alternate source vendor when testing is not required by Paragraph 4.4.1.

4.5 LOT ACCEPTANCE AND LOT CERTIFICATION

This activity pertains to the acceptance testing and flight certification of individual production lots of pyrotechnic devices.

4.5.1 General

Acceptance tests shall be performed on each lot of pyrotechnic devices.

4.5.1.1 Test Plans and Procedures

A detailed acceptance test procedure shall be prepared for each pyrotechnic device. This procedure shall cover the details of both nondestructive and destructive testing. All acceptance testing shall be performed in accordance with approved detailed test plans and procedures. All test fixtures and equipment required to perform acceptance testing shall be identified and detailed instructions for the use of all equipment shall be included. Documentation shall be adequate to permit duplication of testing by other facilities, such as the launch site. Redundant instrumentation shall be used to minimize loss of data. Specific accept/reject criteria shall be established for each required test. Examples of all forms required for documentation of test results shall be included. JPR 8080.5, Standard G-18 is applicable.

4.5.1.2 Radiography

Radiography (Either N-Ray or X-radiography (X-Ray) or both) shall be used in acceptance of all pyrotechnically loaded devices. Since they are generally complimentary to each other, both techniques shall be used where practical and useful. Mandatory radiography for loaded devices is specified in Paragraphs 4.5.2.4.1 and 4.5.2.4.2 for cartridges, boosters, etc, and in paragraphs 4.5.3.2 and 4.5.3.3 for explosive trains.

4.5.1.3 Examination of Product

Each end item assembly shall be examined and the subassembly/component manufacturing records reviewed to verify that the materials, explosive charges, design, construction, dimensions, workmanship, and marking comply with the requirements of drawings and this and other applicable specifications. Parts having defects usually shall be rejected on an individual basis.

4.5.1.4 DLAT Sample Size

The number of parts to be destructively tested from variously sized lots of pyrotechnic devices shall be as follows:

a. Loaded pyrotechnic devices which contain an integral pyrotechnic charge: The number of parts to be fired in DLAT shall be 10% of the lot or 10 units minimum whichever is greater. Lot size equals the final number of units which are presented for formal lot acceptance. Fractional sample sizes 0.5 and above must be rounded upward and sizes below 0.5 must be rounded downward.

b. Inert pyrotechnic devices which do not contain an explosive component but are functioned by a separable cartridge: The number of parts to be fired from various lots of inert pyrotechnic devices will be established by the Project Office based on the criteria in Paragraph 4.5.1.5.

4.5.1.5 Acceptance Tests for Inert Pyrotechnic Devices

Each unit of the lot shall be subjected to a proof load test and a minimum of two units shall be subjected to an ultimate load test. Additional acceptance tests for inert pyrotechnic devices may be accomplished by one of the following methods:

a. Devices that can be functionally verified by the application of pneumatic pressure at an appropriate level of assembly or when completed may be accepted as a lot without a pyrotechnic DLAT firing. This approach requires that each unit in the lot function at an acceptable pressure and then be reassembled maintaining the components as a set. Components that are normally degraded during the functioning must be replaced. If other components are degraded the pressure test must be repeated. These tests may be performed at an appropriate level of assembly.

b. Devices that cannot be functionally verified as specified in Subparagraph a. because the unit would be destroyed must be accepted by pyrotechnic DLAT firings. The DLAT sample size shall not be less than two units.

c. Frangible devices shall be accepted by a minimum of five pyrotechnic DLAT firings. These firings shall demonstrate the required performance margin in a manner dependent on the design of the device. Frangible nuts shall demonstrate the required performance margin with a single production cartridge/charge if dual cartridges/charges are used. The cartridges used to activate these frangible devices shall have met the acceptance requirements of Paragraph 4.5.1.4.

4.5.1.6 Current/Time to Peak Performance Measurements

The data obtained in each destructive test for pressure generating cartridges shall have actual firing current and output pressure versus time recorded.

4.5.1.7 Detonation Performance Measurements

Detonating cartridges or devices shall utilize a pass/fail criteria delineated in the respective procurement specification such as detonation velocity, dent block measurements, swell cap expansion, explosive jet penetration, etc. Neither the device nor the initiator shall fracture, except for the portion immediately surrounding the detonating charge.

4.5.1.8 Environmental Testing

Appropriate environmental acceptance testing will be considered for each pyrotechnic device, either as a nondestructive test on the entire lot or as conditioning on the destructive test samples only.

4.5.2 Cartridge, Booster, Detonators, Initiators, Etc., Acceptance Tests

Prior to delivery and as a condition of acceptance the supplier shall conduct nondestructive tests on each device submitted for acceptance and destructive tests on a random sample of the lot (reference Paragraph 4.5.1.4) as specified in the table below. Acceptance tests need not be limited to those listed below:

ACCEPTANCE TESTS	
Test	Applicable Paragraph
Examination of Product	4.5.1.3
Leakage Test	4.5.2.3
Radiography Test	4.5.2.4
Destructive Performance Tests	4.5.2.5

Sequence of testing shall be specified by the element contractor except that the firing of the lot sample shall be conducted last and all units of this sample shall have undergone all other tests prior to firing.

4.5.2.1 General

Any cartridge found to be defective in any nondestructive test shall be rejected. The number of cartridges to be subjected to destructive testing from various lot sizes shall be in accordance with Paragraph 4.5.1.4. Failure of any device to meet performance requirements shall be cause for lot rejection. Pressure cartridges shall be fired in closed or vented test bombs as appropriate to their specific application per Paragraph 4.5.2.5.1

4.5.2.2 Verification of Explosive Weight

In addition to the requirements of Paragraph 4.5.1.3, weight verification shall be performed on each device per Paragraph 3.10. Verify the device weight and include the manufacturing weight records in the data package.

4.5.2.3 Leakage Tests

4.5.2.3.1 Helium Test

The indicated leak rate for loaded, hermetically sealed pyrotechnic device shall not be greater than 1 X 10^{-6} cc/second of helium when measured at one atmosphere differential pressure at laboratory ambient temperature. Testing shall be in accordance with a procedure approved by the procuring agency/center. Environmental (dust) seals are exempt from this requirement.

4.5.2.3.2 Gross Leak Test

Gross leak testing shall be performed on each loaded, hermetically sealed pyrotechnic device. Gross testing leak shall be performed prior to helium leak testing. Testing shall be in accordance with a procedure approved by the responsible NASA design center.

4.5.2.4 Radiography

4.5.2.4.1 X-Ray Test

When specified in the procurement specification, each device shall be X-Rayed in accordance with ASTM E1742, Standard Practice for Radiographic Examination, to verify compliance to the assembly drawing, to determine that there are no missing or improperly oriented details and to verify that there are no foreign objects or materials present. The views shall be perpendicular to the longitudinal axis, and the number of views shall be the minimum number required to obtain the necessary required information. Two negatives shall be made of each view. The procuring agency shall establish the requirement for retention of radiographs.

4.5.2.4.2 N-Ray Test

When specified in the procurement specification, each device shall be subjected to N–Ray examination in one view in accordance with JSC 20431, NASA JSC Neutron Radiography Specification, to verify that the pyrotechnic mixture is present and properly oriented in accordance with the applicable assembly drawing. Also, there shall be no missing or improperly oriented details and no foreign objects or materials present. The procuring agency shall establish the requirement for radiographic copies and who should retain a permanent file for the original copy. When external finishes, adhesives, potting materials, etc., would reduce the resolution of the N-Ray negative, the radiograph shall be made prior to the application of such materials. Devices loaded with loose powder shall be N-Rayed in an orientation which reveals column height.

4.5.2.5 Destructive Performance Test

4.5.2.5.1 Test Bomb Configuration Control

Detail drawings of test bombs shall be prepared and shall be approved by the element contractor and NASA review team representatives. The actual bomb shall be inspected and stamped to assure complete compliance with drawing requirements. Each bomb shall be permanently identified with part number and serial number. Before and after each series of tests, such as acceptance or qualification, the volume shall be measured and compared with the original volume. The allowable maximum volume shall be established for each bomb and the bomb shall be replaced or reworked, if appropriate, when this limit is exceeded. The bomb shall be cleaned and visually inspected after each firing. The data shall indicate the part, serial number, and actual volume of the bomb used.

CAUTION: Preservatives, water and cleaning solvents may influence the output pressure in closed bomb tests if not removed properly.

4.5.2.5.2 Cartridge Ports

The cartridge ports in test bombs shall duplicate the ports used in the specific vehicle application.

4.5.2.5.3 Pressure Transducers

Each test bomb shall utilize a minimum of two pressure transducers and they shall be standardized to the greatest extent possible to minimize inventory requirements at the contractor, suppliers, and launch sites. The test bomb transducer ports shall be in accordance with the transducer manufacturer's recommendations and completely defined on the test bomb drawing. The installation requirements for the transducer shall be described in detail in the applicable test procedure.

4.5.2.6 Cartridge Body Proof Pressure

Verify requirements that were established in Paragraph 3.6.17.1a.

4.5.3 Explosive Trains Acceptance Tests

Explosive trains include but are not limited to LSC, CDF, MDF, CDC, SMDC, FCDC, assemblies, and charge holders.

4.5.3.1 General

The provisions of Paragraph 4.5.1.3 shall be applicable to these assemblies and components. Additional acceptance tests shall be performed at the levels of assembly shown below:

CDF/MDF/FCDC/SMDC

Nondestructive Tests	Core Charge	Explosive Train Assy Level
X-Ray	Yes	Yes
N-Ray	No	Yes

Destructive Tests	Core Charge	Explosive Train Assy Level
Core Weight	Yes	No
Bending	Yes	No
Detonation Velocity	Yes	No
Performance	No	Yes
Initiation	No	Yes

LSC

Nondestructive Tests	Core Charge	Explosive Train Assy Level
X-Ray	Yes	Optional
N-Ray	No	Optional

Destructive Tests	Core Charge	Explosive Train Assy Level
Core Weight	Yes	No
Detonation Velocity	Yes	No
Penetration	Yes	Yes
Performance	Yes	Yes
Initiation	No	Yes

4.5.3.2 X-Ray Test

All explosive trains, and charge holder assemblies except as specified in Paragraph 4.5.3.1, shall be X-Rayed in accordance with ASTM E1742 to verify compliance with the assembly drawing, to determine that there are no missing or improperly oriented details and to assure that there are no included foreign objects, materials, or unacceptable voids. Each train and charge holder assembly shall be radiographed in at least one view perpendicular to the longitudinal axis and two negatives shall be made of this view. The procuring agency shall establish the requirement for radiographic copies and who should retain a permanent file for the original copy.

4.5.3.3 Neutron Radiographic Test

All explosive trains and charge holder assemblies except as specified in Paragraph 4.5.3.1 shall be examined by N-Ray per JSC 20431 to verify that the pyrotechnic charge components are present and properly oriented in accordance with the applicable drawings. Also, there shall be no missing or improperly oriented details, and no included foreign objects, materials, or unacceptable voids. Each train shall be radiographed in one view along the longitudinal axis. The procuring agency should establish the requirement for radiographic copies and who should retain a permanent file for the original copy. When external finishes, adhesive potting materials, etc., would reduce the resolution of the radiograph, the radiograph shall be made prior to the application of these materials.

4.5.3.4 Core Charges (MDF, FCDC, SMDC,CDF, CDC and LSC)

As a minimum, core charges shall be tested as specified herein.

4.5.3.4.1 Core Weight

Test samples shall be cut from each tube of detonating cord. Each sample shall be a three-inch minimum length. For core weights 250 grains per foot or larger, one-inch minimum samples shall be taken instead of three-inch samples. Samples shall be from each end of each tube and at other specified intervals. Intervals shall be determined by the appropriate NASA design center. Each manufacturing length shall have core weight samples taken from both ends.

LSC/cord core weight samples exceeding the tolerance identified in the end item procurement specification shall result in rejection of either the LSC/cord 100 feet minimum on either side of the failed sample or a manufacturing length on either side of the failed sample, whichever is less.

4.5.3.4.2 Bending

When the application includes bends, bend tests shall be performed as a part of qualification and lot acceptance. Test samples shall be cut from each tube of detonating cord. Each test sample shall be 15 inches minimum length. Samples shall be from each end of each tube and at other specified intervals. Intervals shall be determined by the appropriate NASA design center. A bend radius of five cord diameters or less, measured to the center of the cord, constitutes a bend. These tests shall be performed prior to determining the detonation velocity in accordance with Paragraph 4.5.3.4.3.

4.5.3.4.3 Detonation Velocity

The detonation velocity shall be established for each component that uses HNS, RDX, HMX, or PETN. The detonation velocity shall be measured with an electronic time-interval meter or similar equipment. The established detonation velocity shall have a tolerance sufficient to detect unacceptable performance. When a lot of CDC, CDF, MDF, SMDC, FCDC or LSC contains multiple tubes, only the tube from which the failed detonation velocity sample is taken shall be rejected. The number and location of detonation velocity samples required for a lot of CDC, FCDC, SMDC, CDF, MDF, or LSC shall be established by the responsible NASA design center. Where bending is required, the detonation velocity test shall be performed on the bend samples. The date detonation velocity tests are completed shall be used for establishing the age life of all CDC, FCDC, SMDC, CDF, MDF, and LSC. The Velocity of Detonation test shall be completed within 1 year of the loading of the linear product.

4.6 THREAD INTERCHANGEABILITY REVIEW COMMITTEE

A NASA representative from each affected center, appointed by the Chair, Constellation Pyrotechnic Working Group (CPWG), shall review each pyrotechnic device for thread interchangeability. An engineering drawing, showing thread form and size, shall be submitted to the Chair, CPWG, for each new threaded pyrotechnic device. This review shall be completed prior to the Critical Design Review (reference Paragraph 5.1).

4.6.1 Thread Sizes for Pyrotechnic Devices

Thread sizes shall not be duplicated if the possibility of incorrect installation exists.

5.0 CONFIGURATION AND PROCESS CONTROL

Element contractors shall establish and maintain effective and detailed control of the configuration, manufacturing processes, materials, QA, acceptance, and qualification of all pyrotechnic devices used. This responsibility shall not be delegated. For new devices and for those devices carried over from other programs which require re-qualification, the control baseline shall be the first production lot acquired for vehicle use. Control of the baseline and all changes thereto shall be maintained as long as the device is used in the specified vehicle, and shall include all contractor/subcontractor/ supplier documents, equipment, facilities, instrumentation, etc., related to the design, manufacturing, acceptance, and qualification of the device. The control baselines and all changes thereto shall require approval of the NASA Project Offices, and shall be implemented through a system of reviews as described below. Inert hardware intended for mockup, fit check, or training use does not require phase reviews.

5.1 REVIEWS

A Phase I Baseline Review shall be conducted for each device to establish the control baseline. A Phase II Production Review shall be held for each production lot of each device except as indicated in Paragraph 5.3. A Phase III Lot Acceptance/Certification Review shall be conducted on each lot of qualified pyrotechnic devices prior to shipment from the supplier. Each review shall be conducted by a team consisting of cognizant engineering and S&MA representatives of the responsible NASA Design Center and system contractor. Representatives of the integrating contractor shall be included at the discretion of the NASA Project Office. Each review shall include documents, equipment, facilities, etc., necessary to establish the baseline, control changes, or acceptance, as appropriate.

5.1.1 Conducting reviews for Contractor Furnished Equipment (CFE)

Each Phase review shall be chaired and conducted by a contractor employee who has detailed knowledge of the specific device. The NASA Pyrotechnic Subsystem Manager shall approve the contractor personnel allowed to perform Phase Reviews. This approval shall be by letter from the SSM to the appropriate NASA Project Office and element Contractor's Office.

5.1.1.1 Procedure for approval to chair and conduct Pyrotechnic Phase Reviews

The contractor employee shall demonstrate the ability to effectively perform the following duties:

a. Prepare detailed Pyrotechnic Device Phase Review Agenda for each pyrotechnic device or lot as applicable. The agenda shall contain, as a minimum, the following:
    1. A comparison of baseline record with the supplier's drawing package, specifications, procedures, and instructions to assure compliance.
    2. A comparison of the as-built configuration with the verified baseline.
    3. A comparison of the supplier's drawings, purchase orders, procedures, materials and process certifications, receiving inspection records and certifications to assure compliance.
    4. Documentation of failures, non-conformances, discrepancies, and anomalies.
    5. A verification of the non-destructive and destructive test data based on acceptance test and/or qualification test procedures.
    6. Verification of Acceptance Data Package requirements.

b. Provide copies of the Pyrotechnic Device Agenda to the Shuttle Pyrotechnic Review Team for review prior to the start of the review.

5.2 PHASE I, BASELINE REVIEWS

All development testing shall be completed prior to a Phase I Review. A Phase I Baseline Review shall be conducted for each device to be used in a flight vehicle. For new devices and those devices from other programs which require qualification for new vehicle use, the review shall precede the start of manufacture of the qualification lot or the first lot of carry over devices. The review items shall include, but not be limited to, all drawings (devices, bombs, fixtures, tools, and packaging), procurement specifications, receiving inspection procedures for piece parts, procedures (including acceptance, qualification, manufacturing and processes) materials, parts list, and development test data. The Phase I Review shall result in authorization to proceed with the manufacturing of piece parts following closeout of open review items. The vendor shall not proceed with explosive loading or device assembly until a successful Phase II Production Review (reference Paragraph 5.3) has been completed.

5.2.1 Control Documentation

Following the Phase I Baseline Review, the system contractor shall establish a record set of all approved documents related to the device. This set shall be updated after each Phase II Production Review and shall consist of the following:

a. One copy of each document comprising the baseline.

b. One copy of each revision/change to each document annotated to show the lot effectivity of the change/revision.

c. One copy of the minutes of each production review, including action/open items and their closeout documentation, and one copy of all production review waivers.

d. A lot effectivity matrix of all changes/revisions to all documents.

e. A reference listing of all qualification reports, failure/anomaly reports and their corrective actions.

f. Other material or listings appropriate for a complete history of the device as it may affect vehicle use.

g. Acceptance test procedures.

These documents shall be maintained in the record set or otherwise be readily available for a minimum of 10 years.

5.2.2 List of Controlling Documents

Each system contractor shall publish a single, comprehensive document listing all controlling documents in the record set for each device. The information for each listed document shall include the issuing organization, document number and title, current revision and date, and the lot effectivity history of each document listed. Pages shall be revised when a listed document is changed or deleted, or when a new controlled document is added.

5.3 PHASE II, PRODUCTION REVIEWS

A Phase II Production Review shall be conducted prior to the start of manufacture of each production lot of each device. The Phase II Review shall cover manufacturing/assembly procedures, instructions, acceptance test procedures, qualification test procedures and any other documents used to assemble the part. The review shall assure adequate evaluation and control of all proposed changes to the baseline and/or last production lot, including the potential effect of the changes upon the qualification status of the device. If required, delta qualification tests shall be defined. The review shall also consider any proposed personnel changes and the current certification of personnel. If there is an interval of less than one year between the acceptance of the last lot and the start of manufacture of the next lot of the same device, and where the last and new lots will be identical in all respects including manufacturing, acceptance and QA, a production review for the lot is not required. The Phase II Review shall result in authorization to proceed with the assembly of piece parts, and acceptance testing following closeout of open review items.

5.3.1 Manufacturing

Production lot manufacture shall be constrained by the closeout of open items as required by Paragraphs 5.2. and 5.3.

5.4 PHASE III, LOT ACCEPTANCE/CERTIFICATE REVIEWS

The Phase III Lot Acceptance/Certificate Review shall be conducted prior to issuing a lot certificate, as described in Paragraph 5.4.3. A Phase III Review Team shall consist of cognizant NASA engineering, and NASA S&MA personnel who have detailed knowledge of the specific device. System contractor engineering, and quality representatives shall be included when the contract is managed by the system contractor. NASA direct-support contractor personnel may serve as Phase III Review Team members, in lieu of the NASA team members, if so delegated by cognizant NASA personnel.

5.4.1 Lot Acceptance Data Information

The supplier shall make the following data, as a minimum, available for review by the Phase III review team.

a. Operational/manufacturing records (travelers).

b. Purchase orders.

c. Rework information/inspection records.

d. Operating time logs.

e. System contractor specifications and drawings.

f. Subcontractor specifications and drawings including tooling and test fixtures.

g. Approved change notices, engineering orders, etc., pertaining to drawings and specifications.

h. Drawings of the pyrotechnic device and test fixtures, as required.

i. System contractor/subcontractor acceptance test procedures and test records.

j. One set of radiographs, as applicable.

k. Comparison of the baseline qualified configuration to the as-built configuration.

l. Any other information the Phase III Review Team may wish to use for the assessment of the quality and reliability of each pyrotechnic device.

5.4.2 Lot Acceptance Data Package

The Lot Acceptance Data Package shall be submitted to the element contractor or NASA design center and shall include the following applicable items as a minimum:

a. Certified acceptance reports including the date of manufacture of the devices (and the initiator installed) and the lot number(s) of the explosive material(s) utilized.

b. Certified list of all piece parts by drawing revision number and receiving inspection records. Total lot quantities and/or serial numbers to provide lot production/rejection traceability.

c. Documented final inspection records including each part in the lot. Copies of the N-Ray and X-Ray certifications prepared by the performing vendor listing serial numbers of parts radiographed if X-ray and/or N-ray is required by the procurement specification. X-Ray negatives and N-Ray negatives as required shall be submitted separately prior to the Phase III Review.

d. A copy of the lot acceptance firing data or other performance parameters which may include pressure/time traces with tabulated values, detonation velocity, delay time, or dent block testing.

e. Material tensile strength test results, and requirements with the performing vendor's certification.

f. Statement certifying the formula for the charge is the same as that used for manufacture of the qualification lot. Propellant description sheets including caloric test data for the current powder lot/batch.

g. Lot certification of the initiator lot used and a marriage list of serial numbers of devices in the lot with each mating initiator. Shipping data on the initiator used in device manufacture. This requirement applies only to devices with initiators installed.

h. Weight data for each device in accordance with Paragraph 3.10. For linear products, core load data shall replace pre-load and post load data sheets.

i. Copies of all nondestructive lot acceptance test data which will show leak test information, bridgewire resistance reading, and any other applicable information.

j. Copies of all failure and corrective action records including MRB waivers/ deviations. Current information shall include copies of all descriptive information such as discrepancy reports, squawk sheets, material review records, rejection reports, etc., pertaining to discrepant hardware for the subject lot in review. This information shall include all reports covering discrepancies from receiving inspection records for piece parts inclusive to end item testing prior to shipment.

k. A copy of the explosive classification. The supplier of each pyrotechnic device shall be responsible for obtaining the explosive classification for that device from the Department of Transportation (DOT). A copy of each such classification shall be furnished to the appropriate element contractor, the NASA Project Office, or the integrating contractor.

l. A copy of the Letter of Competent Authority (LCA). The supplier of each pyrotechnic device shall be responsible for obtaining the LCA for that device from the U.S. DOT. A copy of each letter, as it applies, shall be furnished to the appropriate element contractor, the NASA Project Office, or the integrating contractor.

m. A copy of the Material Safety Data Sheet (MSDS). The supplier of each pyrotechnic device shall be responsible for preparation of the MSDS on the current Occupational Safety and Health Act form designated for that device being presented for certification. A copy of each such data sheet shall be furnished to the appropriate element contractor, the NASA Project Office, or the integrating contractor.

n. Lot certificate (reference Paragraph 5.4.3).

o. Receiving inspection records of piece parts.

p. Vendor certification records pertaining to material traceability from raw stock.

q. A copy of the Phase (I, II, III) Review Minutes.

r. Proof pressure test results.

5.4.3 Lot Flight Certificate

A lot flight certificate shall be issued for each lot of pyrotechnic devices. The certificate shall be signed by the cognizant NASA S&MA representative, NASA engineering and the NASA Pyrotechnics Sub-System Manager (SSM). Additional signatures shall include element contractor engineering, and quality representatives when the contract is managed by the element contractor. As a minimum each lot certificate shall contain the following:

a. The lot identification of the end items, date of manufacture, date of the DLAT and date of Velocity of Detonation testing for explosive cord.

b. Each acceptable flight part in the lot by serial number.

c. The serialized marriage or assembly of all major pyrotechnically loaded components at each level of assembly.

d. The lot and serial number of pyrotechnically loaded components and subassemblies.

e. The end item shelf life expiration date based on the completion date of destructive lot acceptance testing, or velocity of detonation testing for linear products. The shelf life of the initiator shall not be considered in determining the shelf life expiration date for the end item.

f. For devices containing integral initiator, such as cartridges, the bridgewire resistance of each initiator shall be recorded. The recorded value shall be transcribed from the appropriate initiator lot certificate.

g. The vendor Contractor And Government Entity (CAGE) code.

h. Deviations/Waivers (list numbers on face of certificate and attach copy to certificate).

i. The lot number of the propellants or explosives loaded in the device.

5.5 QA SURVEYS

QA surveys shall be conducted to evaluate the contractor's compliance to the contractual quality requirements. Each survey shall include examination of operation and documentation system to determine compliance with established requirements. This includes the examination of articles and material to verify the effectiveness of the contractor's quality system. A summary of the survey results shall be documented including problem areas discovered, recommendation for timely correction and prevention of deficiencies, and recommendation for follow-up action. Surveys may be coordinated with the Constellation Pyrotechnics Working Group (CPWG) to avoid duplication of work at common vendors.

5.5.1 Procurement Surveys

The contractor shall schedule and conduct surveys of their major subcontractors to determine compliance with requirements. A schedule shall be prepared in matrix form and shall include all planned surveys for one year. The schedule shall be maintained throughout the duration of the contract.

5.6 DOCUMENTATION RETENTION

Element contractors and suppliers shall retain lot acceptance data on all pyrotechnic devices for a minimum of 10 years from date of manufacture of the lot, or until the lot has been depleted if the shelf life has been extended beyond 10 years, to assure its availability for failure investigations. Suppliers shall not destroy lot manufacturing records and acceptance data without prior approval from the appropriate element contractor.

6.0 PRESERVATION, PACKAGING, AND DELIVERY

6.1 GENERAL

Preservation, packaging, and delivery of pyrotechnics shall be in compliance with one or more of the following:

a. For military air shipments: AFJMAN 24-204, Preparing Hazardous Materials for Military Air Shipments

b. For commercial shipments: CFR, Title 49 Code of Federal Regulations (Parts 100 through 199), Department of Transportation, and IATA DGR, International Air Transport Association Dangerous Goods Regulations Manual

6.1.1 Preservation, Packaging, and Packing

Materials for preservation, packaging, and packing of pyrotechnic devices shall be selected in accordance with the Letter of Competent Authority (LCA) and Department of Transportation (DOT) regulations. Inert pyrotechnic devices are exempt from LCA shipping regulations.

6.1.1.1 Monitoring Devices

Unit packages shall have desiccant and humidity indicators per MIL-P-116, Method II, or MIL-STD-2073-1, Method 50. Card type humidity indicators per MS20003 will be used inside the package. Except for the humidity indicators, monitoring and recording devices are not required.

6.1.2 Marking

The containers shall be indelibly marked in a legible manner in such a way that the marking shall not become damaged when the containers are opened. The marking shall provide the following information:

Lot Number____

Part Name____

Part Number____

Supplier _______________________Date of Manufacture__________________

6.1.3 Shipping Containers

Materials for preservation, packaging, and packing of pyrotechnic devices shall be selected in accordance with the LCA and all directions from DOT or AFJMAN 24-204, depending on the mode of transportation.

6.1.3.1 Marking of Shipping Containers

Shipping containers marking shall include the suppliers' standard marking for address and precautionary handling. All container markings shall meet the applicable requirements of CFR, Title 49 or AFJMAN 24-204, depending on the mode of transportation. Attach copy of DD250 or DD1149 and MSDS to outside of shipping container.

6.1.4 External O-Rings

External O-Rings may be shipped installed or in a separate package.

6.2 SHIPMENT

6.2.1 Data Accompanying Shipments

One reproducible copy of the lot flight certificate shall accompany each shipment from the manufacturer to the vehicle installation site. Also, a letter of Competent Authority Approval applied for by the manufacturer and issued by the DOT shall be included in the shipment, as well as the applicable MSDS for the hazardous material contained within the device. All pyrotechnic devices identified with a program part, lot or serial number, are subject to these provisions.

6.2.2 Report of Shipment

The supplier shall forward to the Transportation Officer of the using facility (test or installation site) a report of shipment for each shipment. This report shall be sent by electrical communication and shall arrive prior to the estimated arrival of the shipment and shall include the name of the shipper, items shipped, item classification, date of shipment, mode of transportation, name of carrier, shipping document or waybill identification, and the estimated time of arrival of the shipment.

6.2.2.1 Eastern Test Range

All shipments of UN classified explosives coming to KSC will be sent to the following address:

NASA Kennedy Space Center
Launch Complex 39
Ordnance Storage Facility

Bldg, K7- 0558

Kennedy Space Center, FL 32899

Notify: Ordnance Storage Facility (Phone) 321-861-0575

Prior to shipping explosives to KSC, the cognizant contractor will be notified by telephone. Information should include devices being shipped, mode of transportation, carrier, class, expected arrival time.

6.3 RECEIPT, STORAGE, AND HANDLING

Receipt, storage, and handling requirements and procedures shall be the responsibility of each user facility utilizing pyrotechnic components and/or assemblies. The Faraday cap shall remain installed on the initiator or all applicable devices except when bridgewire resistance is being tested, inspections are being made or electrical connections are being made.

7.0 LAUNCH SITE OPERATIONS

7.1 PRE-FLIGHT VERIFICATION TESTING (PVT)

PVT shall be performed for all pyrotechnically loaded devices where failure to operate properly would result in Criticality 1 or 1R failure modes (this requirement does not include premature firing failure modes).

A destructive performance test shall be performed at the launch site (or a test facility approved by the appropriate Element Project Office) on one sample from each lot of explosively loaded devices or assemblies scheduled for their initial flight installation. The lot of devices shall initially be shipped to the launch site as required by Paragraph 6.2. If the PVT is to be performed at a location other than the launch site, a sample of the lot shall be shipped in turn from the launch site to the test location (reference Paragraph 6.2). The PVT is performed to assure that no degradation from handling, shipment, or storage has occurred which would result in unacceptable flight performance of that lot. The initial PVT for each lot shall be performed as soon as possible after initial receipt at the launch site. Subsequent PVT's shall be performed within one year prior to flight use of the lot. Shelf life extension tests (reference Paragraph 3.7.1) shall be substitutions for the PVT. PVT shall be performed without induced environmental exposure. The criteria for device performance shall be the same as that for the original DLAT. The test equipment, set-up, instrumentation, firing stimulus, procedures, etc., shall duplicate those of DLAT insofar as practical.

7.2 PREINSTALLATION CHECKOUT

All pyrotechnic items shall receive the following pre-installation checkout.

7.2.1 Flight (Lot) Certification

Verify by part number, lot number and serial number that each item being kitted for flight is identified on a flight certification.

7.2.2 Age Life

At the time of hardware kitting (explosive devices chosen for flight), verify by lot and serial number that age life of those chosen will not be exceeded during the scheduled vehicle flight.

7.2.3 Visual Examination

Perform visual examination for damage or degradation.

7.3 INSTALLATION AND CHECKOUT

For electrically initiated pyrotechnic systems, perform stray voltage checks, circuit resistance check (after all flight connections are made) and high energy squib simulator checks using the appropriate onboard, built in, test or GSE equipment, or that listed below. JPR 8080.5, Standard G-3 is applicable.

Stray Voltage Tester (C72-1127)

Pyro Checkout Module (C72-1138)

7.3.1 Pyrotechnic Circuit Shield Resistance Verification

The resistance of the circuit shields shall be measured between the connector shell and the pyrotechnic cartridge before connecting the circuit connector to the initiator.

7.3.2 Pyrotechnic Firing Circuit Resistance

The allowable firing circuit resistance for each circuit shall be established and specified in the applicable test and checkout procedure.

7.3.3 Arming and Firing Stimulus Verification

The capability of the firing system to deliver the required firing stimulus to the initiator shall be verified by simulated initiator firing on each firing circuit.

7.3.4 Pyrotechnic Firing Circuit Stray Voltage

For electrically initiated pyrotechnics stray voltage at each pyrotechnic connector shall not exceed 0.05 VAC RMS or 0.05 VDC. Stray voltage with firing system armed shall not exceed 0.05 VAC at each pyro connector between line and ground when loaded with a 1 ohm resistor.

7.3.5 Procedures

Detailed procedures shall be established and published for the installation and checkout of all pyrotechnics. These procedures shall include appropriate safety warnings and controls. JPR 8080.5, Standard G-18 is applicable.

7.3.6 Temporarily Installed Hardware

All temporarily installed devices and hardware such as caps, plugs, covers, support bracketry, protective plates etc., shall be cerise red in color and/or shall have red streamers attached to ensure that they are easily identified under casual observation. Inert non-flight pyrotechnic devices shall be gloss red in color per JPR 8080.5, Standard P-7, and/or shall have streamers attached. All temporarily installed hardware and streamers shall be logged on and off the flight systems unless tracked by some other system. Before closeout of any vehicle, the log and area tracking system shall be inspected to ensure that all temporarily installed hardware has been removed.

7.3.7 O-Ring Lubrication

Minimal lubrication shall be used prior to final installation of devices in the vehicle.

7.3.8 Equipment Calibration

Calibration shall be accomplished in accordance with ANSI/NCSL Z450-1, Calibration Laboratories and Measuring and Test Equipment - General Requirements, or equivalent.

7.4 DISPOSITION OF REJECTED PARTS

Pyrotechnic devices which are removed from flight status subsequent to lot certification shall be shipped from the installation site or destroyed as directed by the design organization. All rejected parts shall be color coded blue per Paragraph 3.9.4 immediately after the rejection decision.

8.0 ELECTRICAL CIRCUIT REQUIREMENTS

8.1 GENERAL

Pyrotechnic circuits and power sources shall meet the requirements of Paragraph 3.1. The design of all pyrotechnic electrical circuits associated with pyrotechnic devices shall require approval of the responsible pyrotechnic office. Material selection of components for firing circuits shall meet the requirements of JSC 49774.

Firing circuits shall include a means for limiting current surges resulting from multiple instantaneous firings. Firing circuits shall also include protection for the power supplies to prevent power loss or voltage drops that might result from post-firing short circuits in the initiator.

8.1.1 Firing Control System

The pyrotechnic firing control system includes all electrical circuits for arming and firing of pyrotechnic devices, including logic, monitoring, and checkout circuits. Pyrotechnic firing circuits shall be designed so circuits are not armed until absolutely necessary. Provisions shall be made to promptly disarm pyrotechnic devices when no longer needed. Arm and fire shall be separate functions that are separately controlled and displayed. Manual arm and fire switches shall be physically separate and physically guarded.

8.1.2 Failure Propagation

Failures shall not propagate from one system to another.

8.1.3 Test Points

The capability to verify the redundancy of all pyrotechnic circuits and systems shall be provided. JPR 8080.5, Standard G-8 is applicable.

8.1.4 Pin Shorting

To prevent the possibility of premature firing resulting from short circuits between pins, pyrotechnic circuits shall not share pins in multi-pin connectors with other load carrying circuits.

8.1.5 Malfunction

Malfunction and inadvertent operation of control circuits caused by extremes of ground and flight environments shall be avoided by protective design features.

8.2 FIRING CIRCUITS

The firing circuit for an Electro-Explosive Device (EED) shall consist of that portion of the firing control system which is isolated and which carries the initiator firing current. A separate firing circuit shall be provided for each EED.

8.2.1 Circuit Characteristics

To prevent adverse effects of common mode currents, each EED shall be supplied by a balanced, shielded, twisted-pair line. The line shall not be connected directly to vehicle structure and will be isolated from vehicle direct current returns through a minimum of 100k ohms resistance. Voltage breakdown from the balanced two-wire line to vehicle structure or direct current return shall be greater than 1500 VAC RMS at a frequency of 60 Hertz.

8.2.2 Fusistors

Fusible resistors (fusistors) shall be provided only where necessary to prevent high current surges during EED firing and to limit current and interrupt flow in the event of a post firing short in the EED.

8.2.3 Wire Routing

Firing circuit wiring shall be routed separately (TBR) (in separate trays or conduit) from all other current carrying circuits including electrical power, electrical control, Radio Frequency (RF) transmission lines, and monitoring circuitry. Circuits routed through a single multi-circuit connector do not satisfy this requirement. JPR 8080.5, Standard G-2 is applicable.

8.2.4 Firing Leads

Splicing of firing leads is not permitted on both flight firing circuits and ground test firing circuits. Initiator firing leads shall be configured to prevent incorrect installation (staking or similar configuration definition).

8.2.5 Arm/Disarm Indicator Circuits

Arm/disarm indicator circuits are required and shall be hardwired for mission critical functions, or the indicator circuits shall be at least as reliable as the operational firing circuits. These circuits shall be isolated from firing circuits.

8.2.6 Post Mate Checkout

Each redundant path shall be verified by test. Successful testing is to be performed as late as possible before flight. Post mating checkout shall be conducted, end-to-end, after all possible mating connections have been closed out for flight. The path tested shall be from the firing source to the initiator without risk of inadvertent ignition.

8.2.7 Crimping and Soldering

Crimping is the preferred method of making pyrotechnic circuit connections. Soldering, if used, shall conform to the requirements NASA-STD-8739.3, Soldered Electrical Connections.

8.3 ARMING AND FIRING

8.3.1 Switches

Control circuit arm switches, firing switches, command receiver power switches (if used), and arm and disarm position control switches shall be capable of being locked or safed in the OFF (disarm) position and shall be located in a common area accessible to the crew.

8.3.2 Protection

Firing circuit switching devices shall be protected as required to prevent inadvertent operation or degradation by high voltage spikes or reverse voltages caused by transients due to load switching, RF interference, lightning, etc. Firing circuits shall be designed and certified for lightning protection in accordance with SAE ARP5413, SAE ARP5415, SAE ARP5416, and SAE ARP5577 with lightning environment and related test waveforms as defined in SAE ARP 5412 and lightning strike zones as identified in SAE ARP5414. JPR 8080.5 Standard E-15 is applicable.

8.3.3 Safing

Safing of firing circuits shall be accomplished by removal of the arm command.

8.3.4 Arming Circuits

For those applications where premature firing may result in a catastrophic event, the pyrotechnic system shall be two fault tolerant against inadvertent firing. Control circuits shall include an arming circuit which is energized by a separate signal or action prior to the initiation of the firing signal.

8.3.5 Electrical S&A Devices

Electrical safing and arming shall provide means for interrupting the firing circuit between the firing switches and the initiator. It may be remotely or locally controlled but must provide means for monitoring the status both remotely and locally. Control of the interrupter shall be separate and independent from all other command and/or control systems in the vehicle.

8.3.6 Timing Circuits

Timing circuits used as logic for firing pyrotechnic devices shall be designed to be fail-safe. The primary failure mode shall not result in an unsafe condition.

8.4 ELECTROMAGNETIC COMPATIBILITY (EMC)

8.4.1 Shielding

Twisted shielded pairs shall be used between the initiator and the firing source for all electrically initiated pyrotechnics. Good RF shielding practices; e.g., multiple shield grounding, no opening in shields and RF type shield termination, shall be used. Shields shall be grounded to vehicle structure through the EED connector and body. JPR 8080.5, Standard E-24 is applicable.

8.4.2 Electrical Bonding

Electrical pyrotechnic circuit elements shall be bonded in accordance with class “R” bonding (2.5 milliohms) per the applicable vehicle document.

8.5 CHECKOUT EQUIPMENT

Carry-on checkout equipment for use at the launch site shall be minimized. Provisions shall be made in the circuitry to allow for verification of the test requirements specified in Paragraph 7.3.

9.0 GOVERNMENT AND ELEMENT CONTRACTOR FURNISHED MATERIAL AND EQUIPMENT

9.1 GENERAL

The requirements and procedures of this section pertain to materials and equipment supplied by the NASA and to equipment supplied by one element contractor to another.

9.1.1 Equipment

Special emphasis should be placed upon a source of supply which is experienced in the design, fabrication, and testing for the procurement and supply of pre-existing equipment which is accepted for flight use. NASA retains the right to approve the sources selected. NASA may provide some or all of this equipment to the affected element contractors through appropriate contractual action as GFE.

10.0 FAILURE AND ANOMALY INVESTIGATION AND REPORTING

10.1 GENERAL

Each NASA Project Office and element contractor shall establish a controlled, closed-loop documentation technique for recording, investigating/analyzing, reporting, verifying, correcting, and feeding back information and data on problems and non-conformances (discrepancies) pertaining to pyrotechnic devices and assemblies. Project Offices and contractors shall ensure that the reporting and corrective action systems of subcontractors and supplier conform hereto.

10.2 APPLICABILITY

The requirements herein are applicable to all NASA and contractor/supplier organizations and activities which manufacture, assemble, test, install, or otherwise handle pyrotechnics. They are applicable to flight equipment, launch essential GSE, and other GSE the malfunction of which could create a safety hazard or induce defects into flight equipment. Spares and flight-configured equipment used as test articles are also subject to these requirements.

10.3 EFFECTIVITY

The requirements herein shall be effective with the start of acceptance testing of the qualification lots except that problems which occur prior to that time and which will, or have the potential to, adversely affect safety, contribute to the delay of a scheduled event or which result in a design change shall also conform to these requirements.

10.3.1 Discrepancy Report (DR) Trending

After final acceptance of pyrotechnic devices, all unit rejection non-conformances, such as: X-Ray, N-Ray, dimensional, leakage, bridgewire resistance, IR, and staking, shall be reported for DR trending to the appropriate NASA Engineering Office on the identifying agency's nonconforming discrepancy report. Non-conformances related to fail to fire, or output which are out of specification, or non-conformances which have been identified as requiring recurrence control shall be reported as problems in accordance with Paragraph 10.5.

10.4 INVESTIGATIONS AND ANALYSES

Each problem shall be investigated and/or analyzed to determine its cause and to establish and implement corrective action which will prevent its recurrence. The type and extent of each investigation/analysis will depend on the nature of the specific problem; however, each investigation and analysis shall be covered by a written plan which is approved by the appropriate NASA Project Office prior to its implementation.

10.4.1 Action Upon Problem Occurrence

When a problem occurs in a test, all testing shall be immediately suspended and, consistent with safety to personnel and equipment, no actions shall be taken which would disturb or alter the test setup as it exists at the time of problem occurrence. The problem shall be reported as specified below and a plan of action shall be prepared and approved by the appropriate Project Office. Only then may the investigation of the problem proceed, unless specific authorization for interim action has been issued by the appropriate NASA Project Office.

10.5 REPORTING

Problems as defined in Paragraph 10.3.1 will be reported in accordance with the criteria specified in applicable vehicle reporting requirements. Problem reporting shall be performed in accordance with JSC 28035 for Government Furnished Equipment (GFE) and NSTS 37325 for Contractor Furnished Equipment (CFE).

11.0 DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

The definitions, abbreviations, and acronyms herein shall be applicable and standard to the pyrotechnics subsystems of the spaceflight vehicles.

<u>Acceptance Testing</u> - Tests to determine that a part, components, subsystem, or system is capable of meeting performance requirements prescribed in purchase specification or other documents specifying what constitutes the adequate performance capability for the item in question.

<u>Acceptor</u> - An explosive component which conducts a detonation impulse from a preceding detonating component usually called a donor.

<u>Apex Thickness</u> - Sheath thickness of LSC at apex of vee angle.

<u>Arm/Disarm Device</u> - A device to make (arm) and break (disarm) electrical continuity from the firing controller to the EED.

<u>Assessment</u> - A verification method employing inspection and/or review of design techniques to verify design features which are impossible to verify by test methods. Features such as finishes, tolerances, bonding, identification and traceability, safety wiring, warning and servicing labels, bill of materials, etc., are applicable.

<u>Booster</u> - An explosive charge augmenting the initiating component of an explosive train to cause ignition or detonation of the main explosive charge or to increase the output of the assembly.

<u>Bridgewire</u> - A resistance wire incorporated into an EED to convert electrical energy into heat to cause ignition of the pyrotechnic material.

<u>CAGE –</u> Contractor And Government Entity.

<u>Cartridge</u> - A separable device loaded with propellant or high explosive.

<u>CDF</u> - Confined Detonating Fuse.

Certification - Consists of qualification tests, major ground tests, and other tests and analysis required to determine that the design of hardware from the component through the subsystem level meets requirements.

a. Certification by Testing

   The process of conducting tests which normally are considered qualification tests plus specific additional tests of components and subsystems and higher levels of assemblies required to certify that the hardware design meets established design requirements. Certification testing does not generally include development, piece-part qualification, acceptance, or checkout tests except where such tests are specifically identified as required for certification.

b. Certification by Analysis

   Analysis performed to satisfy certification objectives when testing under simulated mission conditions is not feasible or cost effective, or the need exists to extrapolate test data beyond the performed test points.

c. Certification by Similarity

   Analysis performed to show that an article is similar or identical in design, manufacturing process, and quality control to another that has been previously certified to equivalent or more stringent criteria.

CFE – Contractor Furnished Equipment.

Charge Holder - An assembly consisting of an explosive train permanently mounted in a holder (usually metallic) designed for vehicle installation. The train may be one intended for structural separation or a transfer charge.

Circuit Interrupter - A device used for interruption of electrical circuits usually by means of an internal piston which, by its motion, breaks the contacts between the pins and pin sockets.

Closed Bomb - A fixed volume chamber used for testing the pressure/time characteristics of pressure cartridges.

Confined Detonating Cord (CDC) - A detonating cord surrounded by a flexible sheath of plastic, fiber fabric, or combination thereof that confines the effects of the explosive core. Generally used for energy transfer between multiplexed components in a pyrotechnic system.

Core Charge - A high explosive material contained in a suitably configured sheath, usually of metal. A generic term for both MDF and LSC. The basic component of an explosive train as defined herein.

DC - Direct Current.

Delay Column - The component of a delay element which introduces a controlled time delay in the functioning of a series of explosive events. It consists of a tube of length primarily dependent upon the burning rate of the delay material being used and the time delay required. Sometimes the column consists of a “priming” material at one end to initiate the delay material and a relay charge at the output end to transfer an impulse and augment the output to a succeeding element in the train.

Delay Element - An assembly that consists of an initiating element at one end, a delay column in the middle and a base charge at the terminal end to transfer an impulse to the next succeeding element in the train.

Detonation - The extremely rapid chemical decomposition (explosion) of a material in which the reaction front advances into the reacted material at greater than sonic velocity.

Detonator - A pyrotechnic device capable of initiating detonation in a subsequent high explosive component.

Development Testing - Testing performed with minimum rigors and controls to verify a design approach.

Dielectric Testing - A resistance test utilizing alternating current.

DLAT - Destructive Lot Acceptance Testing

DOD - Department of Defense.

Donor - An explosive component that conducts a detonation impulse out of a detonating charge into a succeeding high explosive charge usually called an acceptor.

DOT - Department of Transportation.

Dud, Dudded - The destruction of the operating or functioning capability of a device; for example, a cartridge or other device which will not function upon receipt of the prescribed initiating stimulus.

EED - Electro Explosive Device (e.g., the NSI-1).

Electrical Circuit Safe/Arm - A device which electro-mechanically interrupts the firing circuit between the initiator and the final firing control device and which provides additional safety from premature firing. (Reference Arm/Disarm).

Element Contractor - Contractor responsible for specific elements (i.e. LAS, CEV, CLV LSAM etc.) of the flight program.

EMC –Electromagnetic Compatibility.

EMI - Electromagnetic Interference.

End Coupler - An integral acceptor and/or donor charge built into the end(s) of an explosive train.

Explosive - A generic term which includes deflagrating, detonating, and pyrotechnic materials.

Explosive Bolt - A bolt that is intended to be fractured at a predetermined point by a contained or inserted explosive charge for the purpose of releasing a load.

Explosive Lot - A specific traceable quantity of an explosive material resulting from a one-time blending or mixing of one or more batches, all of which were prepared within a short time period.

Explosive Train - An assembly of MDF or LSC sealed at both ends, either with or without end couplers or boosters.

Fail Safe - System design which after a single functional failure is still capable of performing its required function. Premature firing is excluded as a failure.

Faraday Cap - The cap applied to the connector end of the NSI-1 to provide an EMI shield to prevent inadvertent firing from RF sources. This cap does not short out the bridgewire.

FCDC - Flexible Confined Detonating Cord.

GFE - Government Furnished Equipment.

GFM - Government Furnished Material.

GSE - Ground Support Equipment.

HMX - Cyclotetramethylenetetranitramine; a secondary explosive. Color - white.

HNS - Hexanitrostilbene; a secondary explosive. Color - buff to pale yellow.

IFU - Initiator Firing Unit.

Igniter Cartridge - A pyrotechnic device designed to initiate burning of a fuel mixture or a propellant.

Indentation Fixture - Steel witness block used in dent test.

Inert Device - A pyrotechnic device which contains no explosive, pyrotechnic or chemical agent.

Initiator - The primary stimulus component in all pyrotechnic devices and systems.

Installation - The assembly of a pyrotechnic device into a vehicle or another assembly in a manner such as to permit removal or disassembly; e.g., a cartridge installed into a mortar or a guillotine into a vehicle.

IPA - Isopropyl Alcohol.

IR - Insulation Resistance.

IRME - Initiator Resistance Measuring Equipment.

Ku-band - 10.9 to 35 Gigahertz per Second.

L/N - Lot Number.

LCA - Letter of Competent Authority.

Lead Azide - A sensitive primary explosive. Color - white.

Limit Load - The maximum load expected on the structure during mission operation including intact abort.

Locked-Shut Test - A test of a device designed to operate with an expanding gas volume (e.g., piston type thruster) in which the moving parts (e.g., pistons) are restrained from movement so that the initial volume remains unchanged and a high over-pressure results. This test demonstrates that the device will not rupture or fragment with restraint on the piston. Testing is performed with redundant charges firing simultaneously, when appropriate.

Lot Certificate - A NASA approved document pertaining to a specific lot of a specific pyrotechnic device which lists all specific serialized parts in the lot that are certified for flight vehicle installation. It is prepared on the basis of manufacturing and acceptance data and represents the status of each device at the time of the certification activity and is not changed as listed devices are used or subsequently undergo a flight worthiness change.

LSC - Linear Shaped Charge. A metal tube containing a core of high explosive, formed into a “V” or chevron shape to produce a cutting jet.

Marriage - The assembly of components, such as the NSI-1, into a cartridge or an explosive train into a charge holder, in a manner intended to be permanent.

Marriage List – A list that defines the serial numbers installed in the next assembly. For example the marriage list for a cartridge would include the serial number for the cartridge as well as the serial number for the initiator installed into it.

MDF - Mild Detonating Fuse. A metal tube containing a core of high explosive usually of circular or similar cross-section.

MRB - Material Review Board.

MSDS - Material Safety Data Sheet.

N-Ray - Neutron Radiography.

NSD - NASA Standard Detonator.

NSI - NASA Standard Initiator.

NSI-1 - NASA Standard Initiator, Type 1 (previously designated as the Standard Manned Space Flight Initiator [SMSI] and the Single Bridgewire Apollo Standard Initiator [SBASI]).

Off-Limits Testing - Those tests designed to evaluate device performance during or after exposure to environments which are more severe than those predicted for mission use.

P/N - Part Number.

Percussion - A method of initiating a pyrotechnic charge by an intentional sudden pinching or crushing of the explosive material, as between a blunt firing pin and an anvil.

PETN - Pentaerythrite Tetranitrate. A secondary explosive more sensitive than RDX or HNS. Color - white.

PIC - Pyrotechnic Initiator Controller.

Piggyback - The practice of backing up one LSC with another by placing one LSC on the back of the LSC performing the cutting such that the liner of the backup charge is in contact with the back side of the cutting charge.

Preinstallation Test - A nondestructive test, or series of tests, performed on a pyrotechnic device prior to its installation in a flight vehicle or test fixture.

Primary Explosive - An explosive material that is very sensitive to heat, impact, and friction as initiating mechanisms. Includes azides, fulminates, etc. Often used as one of the first elements in an explosive train. Example: lead azide

Production Lot - A group of new production components, devices, or assemblies of the same design, construction, and materials fabricated in one unchanging and essentially continuous manufacturing process and submitted for acceptance at one time.

PS-11 - Constant Current Pulse Generator Model PS-11.

psi - pounds per square inch.

PVT - Preflight Verification Test. A firing test performed at the launch site on a sample of the flight lots installed on a vehicle. Tests may be time, vehicle or mission based.

PWG - Pyrotechnic Working Group.

Pyrotechnic Material - A mixture of chemicals designed to produce heat, gas, pressure, or shock.

Pyrotechnics - The generic term used throughout NASA in lieu of “ordnance” to avoid the connotation of weaponry as in “pyrotechnic systems.” “Pyrotechnic devices” include all devices and assemblies containing, or operated/actuated by, propellants and/or explosives including items such as initiators, detonators, S&A devices, cartridges, separation bolts and nuts, pin pullers, linear separation systems, guillotines, valves, disconnects, retractors, thrusters, transfer assemblies, TBIs, shaped charges, Military hardware worn for crew escape, mortars, circuit interrupters, dimple motors, oxygen candles and igniters but specifically excepting large rocket motors.

QA - Quality Assurance.

Qualification Test - A test structured to certify that design requirements have been met.

Random Sample - A sample selected without bias or prejudice.

RDX - Cyclotrimethylenetrinitramine. A secondary explosive. Color - white.

Receptor - Reference “Acceptor”.

Recommended Firing Current - A current recommended to be applied to an EED to cause initiation of the explosive charge and which provides a margin over the “all-fire” current stimulus. Specified as 5.0 amperes minimum for the NSI-1.

Redundancy

> Single - A single-redundant system is one which will sustain one failure of an assembly/component and still retain the capability of performing the intended function. This level of redundancy is attained by adding one like assembly/component to the system. For example, if one battery is required to provide a source of firing current, one additional battery provides single-redundancy of the current source and the batteries are said to be redundant.
>
> Dual - A dual-redundant system is one which will sustain two failures of one assembly/component and still retain the capability of performing the intended function. Such a system is frequently termed “fail operational/fail-safe”. This level of redundancy is attained by adding two like assemblies/components to the system. For example, if one battery is required to provide a source of firing current, two additional batteries provide dual-redundancy of the current source and the batteries are said to be dual-redundant.
>
> Design - Design redundancy exists when redundant devices are of different designs, usually having different failure modes. For example, if an umbilical is severed by either a guillotine or an LSC, both mounted so as to perform the function, the severing system is both device redundant and design redundant.

RF - Radio Frequency.

RFI - Radio Frequency Interference.

RMS – Root Mean Square.

S&A - Safe and Arm.

S&A Device - A mechanical device for interrupting an explosive train (safe) when required to be in the unarmed condition and aligning the train so as to render it operative (armed) when required to be ready to fire.

scc - standard cubic centimeters.

Secondary Explosive - Explosive materials that are relatively insensitive to heat or impact and must be initiated by a suitable primary explosive or another secondary explosive. Secondary explosives are generally more brisant and more powerful than primary explosives; synonymous with “high explosive”.

Sensitivity - The characteristics of an explosive or component which express its susceptibility to initiation by externally applied energy. May apply to electrical, shock, or other stimuli.

Severance Target - Witness specimen used for evaluating performance of a detonating cutting charge such as MDF or LSC.

SII – SRM Ignition Initiator.

SMDC - Shielded Mild Detonating Cord.

Squib - A general term usually meaning any one of many EEDs such as an NSI-1.

S&MA - Safety and Mission Assurance.

Staking – The process of permanently modifying keyways on the electrical connector end of the NSI to prevent incorrect connection of the wrong firing leads.

Standoff - The distance between the base of a shaped charge liner and the target material.

SSM – Sub-System Manager.

System Contractor - Contractor responsible for specific systems of the flight program.

Test Bomb - A chamber into which cartridges are test fired to establish or verify performance characteristics such as the output pressure vs. operating time. These fixtures have a fixed, known volume (see also “closed bomb” and “vented bomb”).

Thru-Bulkhead Initiator (TBI) - An explosive initiator that provides a detonation transfer via a shock wave through an integral bulkhead without rupturing the bulkhead. Explosive material is packed intimately in cavities on both sides of the bulkhead.

Transfer Charge - A sealed assembly containing explosives designed to provide an alternate explosive path between explosive trains as in an elongated container containing bulk explosive to bridge the gap between two end-to-end positioned trains.

UN – United Nations

VAC – Volts, Alternating Current.

VDC - Volts, Direct Current.

Vented Bomb - A closed bomb with an orifice to control venting of the gas pressure to the atmosphere.

X-Ray - X Radiography.

12.0 INDEX

A-1 APPENDIX ONE

The requirements listed in this appendix are requirements for programs electing to use the NSI-1. If the program selects the NSI as their primary initiator these requirements shall be invoked.

A-1.1 NASA Standard Initiator (NSI)

JSC/SEB26100001, Initiator, NASA Standard, shall be the standard Electro Explosive Device (EED) and shall be Government Furnished Equipment (GFE) to all users by JSC, and shall conform to JSC/SKB26100066, Design and Performance Specifications for NSI-1 (NASA Standard Initiator-1).

A-1.1.1 Authorized Connector Configurations

The only connector configurations (straight backshell) authorized for use on NSI-1 connections shall be P/Ns: NBS9GE8-2SE, -2SF, -2SG and -2SH. These four authorized configurations are restricted from use in non-pyrotechnic circuits in the vicinity of an installed NSI-1.

Use of any other configuration (straight and/or right-angle backshell) on an NSI-1 shall require a waiver/deviation to this specification. A waiver/deviation for use of right angle connector shall include the methods used to prevent backshell/endbell loosening.

A-1.1.2 Insulation Resistance (IR) Testing

Subsequent to NSI-1 lot acceptance tests, Insulation Resistance Testing shall be limited to the following:

a. In cartridge lot acceptance tests: Destructive test sample, one test per part at 250 VDC; deliverable units, one test per part at 50 VDC (maximum). No IR test is to be performed prior to higher assembly buildup.
b. Installation site receiving test: One test per part is optional at 50 VDC maximum.
c. Flight vehicle pre-installation test: One test only (250 VDC) per part is mandatory. Further IR testing shall be performed at 50 VDC maximum.
d. Firing tests: One test per part is optional at 250 VDC maximum.

A-1.1.3 Age Life

The life of the NSI-1 and the SII shall be 10 years from the date of manufacture.

A-1.1.4 Verification NSI-1 Characteristics

Verification of NSI-1 characteristics shall be performed during acceptance testing of the next assembly (i.e. acceptance testing of the common cartridge) and prior to installation at KSC.

A-1.1.4.1 Bridgewire Resistance Test

The bridgewire resistance of the NSI-1 in each cartridge shall be measured and recorded as a part of hardware acceptance testing. The measured resistance shall be 1.05 ± 0.10 ohms at laboratory ambient temperature. Test current shall be limited to 0.02 ampere for a maximum of one minute. The applied voltage shall not exceed 1.0 volt when the measuring circuit is terminated in an open circuit. All units which fail to meet this requirement shall be documented on a problem report. Lots with units varying more than 0.05 ohms shall be evaluated independently. A new baseline resistance can be established when the vendor resistance measurements for the lot is determined to be incorrect.

A-1.1.4.2 Staking Verification

Verify acceptance data pack contains documentary evidence that the NSI-1 installed in the device is the correct configuration (dash number) for the type of device being delivered. The NSI-1 dash number is controlled in the baseline documentation for the device. The dash number is electro-etched on the flange of each NSI-1.

A-1.1.4.3 Insulation Resistance (IR) Test

NSI-1 IR tests shall be performed on the DLAT sample at 250 VDC using a megohmeter. The measured value shall be 2.0 megohms minimum and any part failing this test shall be rejected and a replacement part shall be selected for the DLAT sample. IR tests on other cartridges in the lot shall be performed at 50 VDC maximum.

A-1.1.4.4 NSI-1 Lot Certification Verification

The flight certification of all NSI-1 used in the cartridge lot shall be verified by reference to the parts and serial numbers listed in the appropriate NSI-1 lot certificate supplied for the NSI-1 lot(s).

A-1.1.5 Disposition of NSI-1

At the completion of lot acceptance of each lot of cartridge assemblies, the cartridge supplier shall account for, and dispose of, all NSI-1 received for the manufacture of that cartridge lot by one of the following methods:

a. Delivery to customer as an integral component of a cartridge assembly.

b. Return of acceptable parts to the NASA stock from which received (units surplus to the manufacturing operation).

c. Ship to NASA JSC, Attn: EP6 (units rejected or damaged or disassembled from cartridges).

A-1.1.6 NSI-1 Mating Electrical Connector

MSFC connector 40M38298 shall be used throughout the vehicle as the electrical mating connector to the NSI-1. Connector indexing configurations are shown in the

NASA JSC control drawing, NSI SLB26100052. JPR 8080.5, Standard E-1 is applicable.

NSI Indexing and Dash Numbering

Reference Configuration Control	Drawing SLB26100052
Basic P/N & Configuration	Designation
SEB26100001 -1XX	Prototype, Develop & Experimental
-2XX	Flight Configuration
-X1X	Spanner Type (Weld Washer)
-X2X	Not Designated
-X3X	Not Designated
-X4X	Not Designated
-X5X	No Weld Washer
-8XX	Inert Device
-XX1	Keyways 1 and 6 closed (Nonflight)
-XX2	Keyways 2 and 6 closed (Flight)
-XX3	Keyways 3 and 6 closed (Flight)
-XX4	Keyways 4 and 6 closed (Flight)
-XX5	Keyways 5 and 6 closed (Flight)
-XX6	Keyways 1 and 2 closed (Flight)
-XX7	Keyways 1 and 3 closed (Flight)
-XX8	Keyways 1 and 4 closed (Flight)
-XX9	Keyways 1 and 5 closed (Flight)
-XX0	All Keyways Open

Mating Connectors

NSI Configuration (Dash #)	Straight Backshell	Right Angle Backshell
-XX6	9GE8-2SE	8GE8-2SE
-XX7	9GE8-2SF	8GE8-2SF
-XX8	9GE8-2SG	8GE8-2SG
-XX9	9GE8-2SH	8GE8-2SH
-XX0	ALL	ALL

A-1.1.7 General

The firing stimulus to the NSI-1 shall be applied by the Initiator Firing Unit (IFU) (NASA P/N SED26100128-301), Pyrotechnic Initiator Controller (PIC) (Model GSE-01) or Constant Current Pulse Generator (E & R Development Company Model PS-11). The firing mode shall be that which will be experienced in flight; i.e., capacitor discharge or constant current. In the constant current mode the PS-11 Constant Current Generator shall be set at 5 amperes and in the capacitor discharge mode. The PIC and IFU may be used for capacitor discharge firing and will provide an output from a 680 μf capacitor charged to approximately 40 VDC. For cartridges which are intended to be fired in flight in either mode, the acceptance sample shall be appropriately divided and part fired in each mode. The pressure/time trace for each firing shall be recorded using a NASA approved and calibrated data system.

A-1.2 GFE AND GOVERNMENT FURNISHED MATERIAL (GFM)

A-1.2.1 NSI-1, NSI-1 Output O-Ring, and NSD

The NSI-1, SEB26100001, NSI Output O-Ring, the SRM/SII, SED26100107 and the NSD, SEB26100094, shall be supplied by JSC to all vehicle users. JSC shall maintain at least a dual supply source capability for the NSI and NSD. The NSI-1 and NSI Output O-Ring will be made available for non-Shuttle U.S. Government use subject to the provision in Paragraph A-1.2.4.

A-1.2.1.1 NSI O-Ring Cleaning

When required, o-rings shall be cleaned with IsoPropyl Alcohol (IPA). O-rings shall not be submersed in IPA. If o-rings are cleaned with IPA they shall be dried for a minimum of 30 minutes. Examine for damage such as nicks or cuts and contamination.

A-1.2.2 Forecasts of Vehicle Requirements

Any program requiring NSI's or NSD's shall follow the methods listed in this section for obtaining NSI's or NSD's. Each element contractor shall submit an annual 5-year forecast of NSI-1 and NSD requirements to the NASA/JSC pyrotechnics officer which shall review the contractor forecast, and requirements for other, non-contractor use (e.g., MSFC in-house use) and forward the overall system forecast to the applicable vehicle Project Office for approval and inclusion in the JSC budgetary estimates. Each forecast is due on November 1, and shall include the estimated requirements for the next five government fiscal years. The first two years of each forecast shall be by fiscal quarters and the remainder by year. Detailed justification for the first year requirements shall be included. NASA Form 558 shall be used. The following assumptions shall be used in estimating requirements:

a. Each flight and backup lot of cartridges and independently installed NSI-1 and NSDs will be delivered to the installation site six months prior to the first scheduled use of the lot.
b. No reserve of NSI-1 or NSDs for contingencies shall be included.

A-1.2.3 Requests for Shipments

Each system contractor shall submit a request for specific shipments of NSI-1 and NSDs to the appropriate NASA Project Office which shall review the request, add requests for other required shipments, and forward the combined requests to the applicable program office. Each request shall include detailed shipping information. (Upon approval by the Flight Engineering and Vehicle Management Office, these requests will be the basis for JSC configuration and shipping direction to the NSI-1/NSD stock manager [the supplier] and for planning and revising program reserves.) Consignees for NSI-1/NSD shipments shall be the cartridge manufacturers, the installation sites (for independently-installed NSI-1/NSD) or the test sites (for NSI-1/NSD to be used in development tests), as appropriate.

A-1.2.4 GFE Requirements

The NSI-1 and NSI output o-ring can be made available for non-NASA U.S. Government projects. Non-U.S. Government requirements are not supported. The NSD is not available as GFE outside of NASA. Availability of the NSI-1 and NSI output o–ring is subject to the following conditions:

a. Written request shall be made to the Flight Engineering and Vehicle Management Office, with a copy to JSC Code EP5, 24 months prior to desired delivery. The request shall include the name of the program, contact name and phone number, quantity of units desired, configuration, and destination for shipping purposes. Conditional acceptance and an estimate of costs will be provided in 60 days.

b. Full funding shall be provided no later than 12 months prior to desired delivery date. Funds shall be provided by an intra-government funds transfer. Transfer of travel funds may be required for manufacturing coverage by JSC engineering and quality personnel. Funding cannot be directly accepted from U.S. government contractors. Requests for less than 1,000 units are subject to accumulation of sufficient orders to process manufacture of at least 1,000 units. Final acceptance of requests and establishment of a delivery date are subject to the above conditions.

c. Final shipment of GFE shall be made on an agency to agency property transfer.

A-1.2.5 Accountability

NSI-1 and NSD are accountable by part, lot, and serial number and are supplied for the specific use stated in the Request for Shipment (reference Paragraph A-1.2.3). Project Offices and system contractors are responsible for assuring the NSI-1 and NSD are used only for authorized U.S. Government purposes. Upon receipt of a shipment from NASA stock, the accountability is transferred from the NASA stock manager (the supplier) to the consignee. Cartridge manufacturers receiving NSI-1 are accountable for the NSI-1 until dispositioned as indicated in Paragraph A-1.1.5.

A-1.2.6 Faraday Caps

Each NSI-1 is shipped from NASA stock with an installed Faraday cap, SEB26100060–301, or an equivalent protective device which is reusable. Each site accumulating these caps (e.g., cartridge manufacturers, installation, and test sites) shall periodically ship the accumulated caps to JSC/Energy Systems Test Branch, for appropriate inspection, refurbishment, and reissue to suppliers.

A Faraday cap, SEB26100060-301 or JSC approved equivalent, shall be affixed to all NSI-1 and NSI-based cartridges during shipment.

A-1.2.7 NASA Equipment

NASA equipment such as the IRME, the PS-11 Constant Current Pulse Generator, the IFU, and the PIC Model GFE-01, shall be supplied by JSC to NASA users on as required basis. JSC shall maintain and perform calibrations subject to the provision in Paragraph A-1.2.8.1.

A-1.2.8 Initiator Resistance Measuring Equipment

The IRME, P/N SAD38111063 (C72-1109), is a digital ohmmeter designed for very accurate measurement of the bridgewire resistance of the NSI-1. The use of this equipment is required only during pre-installation testing of the NSI-1 and NSI-1 based cartridge assemblies and in lot acceptance testing of the NSI-1. The IRME shall be GFE from JSC. One IRME shall be located at each NSI-1 supplier and one at each facility where NSI-1/cartridges are installed in flight vehicles.

A-1.2.8.1 Calibration

The IRME requires field calibration prior to each use. Field calibration shall be performed in accordance with the IRME manual using the IRME calibration resistor. The calibration resistor shall be calibrated by a JSC approved laboratory or returned to JSC for calibration. A calibration sticker with the control number and recall date shall be attached to the calibration resistor.

A-1.2.9 PS-11 Constant Current Pulse Generator

The PS-11 Constant Current Pulse Generator is a commercial constant current pulse generator manufactured by E & R Development Company, Palos Verdes, CA. It may be used to fire the NSI-1 at the device or system level during qualification, acceptance, and system level tests when the constant current mode is specified.

A-1.2.9.1 Calibration

The PS-11 Constant Current Generator is to be calibrated by an approved calibration laboratory using equipment traceable to the National Institute of Standards and Technology. Calibrations are to be performed in accordance with the manufacturer’s recommendations.

A-1.2.10 Initiator Firing Unit

a. NASA P/N SED26100128-301. The IFU (-301) is a portable firing unit provided as GFE by JSC. It provides a firing stimulus from a capacitor bank of 680 microfarads and a circuit tester to verify firing circuit continuity. The charging voltage for the capacitor bank is fixed at 40 ±1.0 VDC. The IFU (-301) may be used to fire the NSI-1 at the device or system level during qualification, acceptance, and systems test when the capacitor discharge mode is specified.

b. NASA P/N SED26100128-303. The IFU (-302) is a portable firing unit provided as GFE by JSC. It provides a firing stimulus from capacitor banks of either 680 microfarads or 1000 microfarads and a charging voltage of 5 to 45 ±0.2 volts Direct Current (DC) in 5 volt increments. It also provides a circuit tester to verify the firing circuit continuity. The IFU (-302) may be used to fire the NSI-1 at the device or system level during qualification, acceptance, and systems level tests when the capacitor discharge mode is specified.

A-1.2.10.1 Calibration

The IFUs (-301 and -302) shall be returned to JSC/Energy Systems Test Bunch, annually for preventive maintenance and calibration. The calibration shall be performed in accordance with approved procedures and shall be verified by S&MA.

A-1.3 Pre-installation Checkout

All pyrotechnic items shall receive the following pre-installation checkout.

A-1.3.1 Flight (Lot) Certification

Verify by part number, lot number and serial number that each item being kitted for flight is identified on a flight certification.

A-1.3.2 Age Life

At the time of hardware kitting (explosive devices chosen for flight), verify by lot and serial number that age life of those chosen will not be exceeded during the scheduled vehicle flight.

A-1.3.3 Visual Examination

Perform visual examination for damage or degradation.

A-1.3.4 NSI-1 and Faraday Cap Inspection and Cleaning

When required, the NSI-1 and Faraday cap shall be cleaned as follows.

CAUTION: Provide operator protection.

a. Using a 10X magnifier, visually inspect the parts for foreign material such as hair, lint, metal particles or films, flakes of epoxy, plating or body material, or products of corrosion.
b. If contaminated blow connector end of NSI-1 and Faraday cap out with gaseous nitrogen and re-examine.
c. If contamination is still present, dip a camel hair brush in methanol or Freon TF and clean contaminated surfaces.
d. Blow connector and cap dry with gaseous nitrogen and re-examine.

A-1.3.5 O-Ring Cleaning

When required, o-rings shall be cleaned with Isopropyl Alcohol (IPA). O-rings shall not be submersed in IPA. If o-rings are cleaned with IPA they shall be dried for a minimum of 30 minutes. Examine for damage such as nicks or cuts and contamination.

A-1.3.6 Bridgewire Resistance

Verify that the bridgewire resistance is 1.05 ± 0.10 ohms and is within 0.05 ohms of the value recorded on the appropriate lot certification. The resistance shall be measured with the Initiator Resistance Measuring Equipment (IRME) (NASA P/N SAD38111063/

Rockwell International P/N C72-1109). All units which fail to meet this requirement shall be documented on a problem report. Lots with units varying more than 0.05 ohms shall be evaluated independently. A new baseline resistance can be established when the vendor resistance measurements for the lot is determined to be incorrect.

A-1.3.7 Insulation Resistance

NSI-1 IR tests shall be performed at 250 VDC per Paragraph A-1.1.2 on each flight, spare, and PVT NSI-1 and NSI based cartridge. Parts failing to meet the 2.0 megohm minimum requirement shall be rejected on an individual basis and replacement parts re-kitted. Hardware kitted for flight shall be subjected to the 250 VDC insulation test prior to kitting one time only. If retest is required, 50 VDC shall be used on a component.

A-1.4 INSTALLATION AND CHECKOUT

For electrically initiated pyrotechnic systems, perform stray voltage checks, circuit resistance check (after all flight connections are made including NSI-1 connections) and high energy squib simulator checks using the appropriate onboard, built in, test or GSE equipment, or that listed below. JPR 8080, Standards G-3 and E-11 are applicable.

Stray Voltage Tester (C72-1127)

NSI-1 Load Simulator

Pyro Checkout Module (C72-1138)

A-1.4.1 Pyrotechnic Circuit Shield Resistance Verification

The resistance of the circuit shields shall be measured between the connector shell and the pyrotechnic cartridge before connecting the circuit connector to the NSI-1.

A-1.4.2 Pyrotechnic Firing Circuit Resistance

The allowable firing circuit resistance for each circuit shall be established and specified in the applicable test and checkout procedure.

A-1.4.3 Arming and Firing Stimulus Verification

The capability of the firing system to deliver the required firing stimulus to the NSI-1 shall be verified by simulated NSI-1 firing on each firing circuit.

A-1.4.4 Pyrotechnic Firing Circuit Stray Voltage

Stray voltage at each pyrotechnic connector shall not exceed 0.05 VAC RMS or 0.05 VDC. Stray voltage with PICs armed shall not exceed 0.05 VAC at each pyro connector between line and ground when loaded with a 1 ohm resistor.

A-1.4.5 Procedures

Detailed procedures shall be established and published for the installation and checkout of all pyrotechnics. These procedures shall include appropriate safety warnings and controls. JPR 8080, Standard G-18 is applicable.

A-1.4.6 O-Ring Lubrication

Minimum lubrication shall be used prior to final installation of devices in the vehicle.

A-1.5 DISPOSITION OF REJECTED PARTS

Pyrotechnic devices which are removed from flight status subsequent to lot certification shall be shipped from the installation site or destroyed as directed by the design organization. All rejected parts shall be color coded blue per Paragraph 3.9.4 immediately after the rejection decision.